AD-786 568

WATERBORNE DEBRIS IN MARINE POLLUTION INCIDENTS

BATTELLE COLUMBUS LABORATORIES

PREPARED FOR
COAST GUARD

MARCH 1974

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its content or use thereof.

The contents of this report of not necessarily reflect the official view or policy of the Coast Guard, and they do not constitute a standard, specification or regulation.

This report, or portions thereof, may not be used for advertising, publication, or promotional purposes. Citation of trade names and manufacturers does not constitute endorsements or approval of such products.

G. J. BUDRIDGE
Commander, U. S. Coast Guard
Acting Chief, Environmental and Transportation Technology Division
Office of Research and Development
U. S. Coast Guard Headquarters
Washington. D. C. 20590

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-108-74		AD-786 568

4. Title and Subtitle
WATERBORNE DEBRIS IN MARINE POLLUTION INCIDENTS

5. Report Date
March 1974

6. Performing Organization Code

7. Author(s)
J. A. Hancock, R. P. Jacobs, M. R. Knapp, and J. S. Glasgow

8. Performing Organization Report No.

9. Performing Organization Name and Address
Battelle
Columbus Laboratories
Long Beach Research Facility
965 Harbor Scenic Way
Long Beach, California 90802

10. Work Unit No.
4111.5.3

11. Contract or Grant No.
DOT-CG-23223-A-11

12. Sponsoring Agency Name and Address
Department of Transportation
United States Coast Guard
Office of Research and Development
Washington, D.C. 20590

13. Type of Report and Period Covered
Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Floating debris has greatly hindered the cleanup of spilled fluids in several pollution instances. This debris has hampered the use of pollution-response equipment and has presented a major materials-handling and disposal problem.

The types of waterborne debris found in coastal, harbor, and estuarine areas are described in this report. Regional variations of the types and quantities of debris, the sources of this debris, and natural effects on concentration and quantity are described.

Current debris-handling practices used in oil spills were researched. Equipment used for handling debris was identified and evaluated. Other equipment not now used for debris handling in spills, but showing potential, was considered. Necessary performance considerations for debris-handling equipment are listed.

Effects of debris on pollution-response equipment were established. Current design features and protection techniques to minimize or negate debris effects were also researched.

17. Key Words
Debris, Oil spills, Debris cleanup equipment, Pollution-response equipment, Waterborne debris

18. Distribution Statement
Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	465	9.25/2.25

Form DOT F 1700.7 (8-69)

FINAL REPORT

on

WATERBORNE DEBRIS IN MARINE POLLUTION INCIDENTS

Prepared for

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development

March 1974

by

J. A. Hancock, R. P. Jacobs, M. R. Knapp,
and J. S. Glasgow

BATTELLE
Columbus Laboratories
Long Beach Research Facility
965 Harbor Scenic Way
Pier J - Berth 249
Long Beach, California 90802

PREFACE

This program was performed under the technical direction of LT Donald S. Jensen of the Office of Research and Development, United States Coast Guard. Without his interest and direction, the objectives of the program could not have been accomplished. The many individuals and organizations who enthusiastically contributed the base of data used in the generation of this report are also acknowledged and are listed in Appendix A.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

Page

CHAPTER IV. EFFECTS ON AND PROTECTION OF POLLUTION-RESPONSE EQUIPMENT FROM DEBRIS IN OIL SPILLS

TABLE OF CONTENTS
(Contents)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

CHAPTER I. PROGRAM SUMMARY

A. INTRODUCTION

The United States Coast Guard, in undertaking its responsibility to prevent and control maritime pollution, is engaged in research and development activities relating to pollution-response equipment. These activities, along with firsthand experience in oil-spill incidents, indicated that a need existed for determining the types of waterborne debris that could be expected in spills, and the effects that debris would have on spill-recovery equipment and operations. This report describes the results of a task undertaken by the Long Beach Research Facility of Battelle's Columbus Laboratories, under contract to the Coast Guard Office of Research and Development, to provide such information. The specific objectives of this task were to

(1) Determine the types, sizes, and quantities of debris that could be expected in oil-spill situations on the navigable waters of the United States

(2) Establish the state of the art of both debris-handling and -removal techniques and debris-protection techniques for pollution-response devices

(3) Recommend specific problems and potential solutions in the debris-handling, -removal, and -protection areas that require further research and development effort.

The geographical scope of the task encompassed the saltwater contiguous zone of the continental United States and Hawaii from tidal estuaries to 50 miles offshore. The near-coastal areas of the Mississippi and Columbia River areas were also considered. Other freshwater rivers and canals entering the coastal area were considered only as sources of debris entering the zones of interest.

The program was performed by dividing the effort into four major subtasks:

(1) Determine the type, quantity, and factors affecting the quantity of debris in the various areas

(2) Identify equipment presently used for or available for debris handling, evaluate that equipment, and recommend new equipment or equipment concepts where necessary

(3) Determine the effects of debris on pollution-response equipment

(4) Identify current design features and techniques for protection of pollution-response equipment from debris, and recommend new equipment or techniques where necessary.

Accordingly, this report is divided into chapters which describe the results of the subtasks listed above. Chapters II and III describe the results of the first and second subtasks, respectively; and the results of the third and fourth subtasks are combined in Chapter IV.

B. PROGRAM APPROACH

It was observed during the initial phases of the program that reference material concerning the subjects of the study was, in general, very limited and, in many cases, nonexistent. The data-collection effort was, therefore, directed toward gathering as much information as possible from as many sources as was practical within the scope and time frame of the program. Where possible, the information concerning the debris situation in a given area, or concerning the use of a given piece of equipment, was sought from several sources with similar experience. This was done to increase the objectivity of otherwise somewhat subjective information.

Information was obtained mainly by telephone and in-person interviews. Much of the debris information resulted from interviews with individuals from local offices of the Coast Guard, the Army Corps of Engineers, spill-cleanup contractors, port authorities, and the Environmental Protection Agency. Some information was also obtained from Army Corps of Engineers publications concerning drift-removal programs. Sources of information on debris-handling equipment generally included manufacturers of present and potential debris-cleanup equipment, the Army Corps of Engineers, and spill-cleanup contractors. Debris effects and protection information

sources included spill-cleanup contractors, the Coast Guard, and the manufacturers of booms and skimmer equipment. For a complete list of information sources, the reader is referred to Appendixes A, B, and C.

Note that the information presented in this report may in some cases not completely describe the situation encountered or the difficulties involved with the use of equipment. To completely describe all the situations, effects, and specific equipment for all situations covered in this study would require a mammoth effort, orders of magnitude greater than this study. This report should be considered a survey which describes general trends and identifies some of the more critical problems in the areas of interest.

C. RESULTS

1. Debris Type and Quantity

In general, most of the man-made floating debris encountered throughout the United States is wood, while most of the natural debris in many areas is marine growth and, to a lesser extent, natural wood.

a. Debris Sources

The relative quantity of debris found in a given area varies greatly from location to location, depending on population density, level and age of shorefront development, proximity to major rivers which flood and bring down large quantities of debris, severity of local storms, magnitude of tides (especially flood tides), the extent of logging activities, and the quantity of abandoned and decaying vessels and structures within an area. For a given area, the concentration of debris in a location is affected by winds, waves, currents, and geographical considerations. All of the factors listed above are discussed in detail in Chapter II.

b. Regional Debris Situations

The floating debris found in New England, Northeast, and Mid-Atlantic ports is mainly driftwood that originates from decaying shorefront structures and vessels. Quantities found range from moderate in ports such as Providence and Boston, to heavy in the ports of New York and Baltimore. Debris in these areas could be a problem in oil-spill recoveries. The debris found in the coastal and offshore areas of these regions is moderate, consisting mainly of natural growth such as eel grass, marsh grass, and seaweed. During severe flooding, such as that which occurs during and after a hurricane, large quantities of floating wood can be present in the rivers and estuaries of this area. This wood has been and will be a hindrance to spill-cleanup operations in these locations.

Debris found in the North and South Carolina and Florida Coastal areas consists mainly of natural growth such as lily pads and hyacinth. The quantity of this material on the water can be locally heavy during certain parts of the year. Some floating wood is also present in the rivers of the region after heavy storm activities.

Very small quantities of debris are present in the open-ocean area of the Atlantic. The debris that is found is scattered over a large area and is encountered piece by piece.

The Gulf Coast region is generally free of debris except for the Mississippi River and the Port of Houston. The Mississippi contains floating wood in heavy quantities during flooding. The Port of Houston area has heavy debris present, consisting mainly of municipal trash from the metropolitan Houston area. Oil spills in both areas have been and would be greatly involved in debris.

The Gulf of Mexico has a debris concentration similar to the Atlantic Ocean, consisting of only occasional pieces of debris scattered over large areas.

The floating material found in the California coastal area consists mainly of kelp located in the immediate offshore waters. These kelp beds are extensive throughout the state, being heaviest in the southern and central areas. The Port of San Diego is relatively free of debris, with the

exception of some random wood and municipal trash. The Los Angeles/Long Beach Harbor areas normally have light debris concentrations. Immediately after a storm the concentration of wood, natural growth, and municipal trash can become locally moderate to heavy. San Francisco Bay has debris concentrations that vary from moderate to severe, depending on tides and storm activity. Most of the debris in the Bay is wood from derelict structures and vessels, with municipal and shipping trash also being common. The quantity of debris in the Bay has been a major problem in many of the local oil spills to date.

The debris concentrations in the Northern California, Oregon, and Washington open-water coastal areas are light to moderate, consisting mainly of logs, logging debris, and kelp. In the estuaries and sheltered bays of this region, the local logging debris concentrations can become heavy. The Columbia River can have locally heavy wood debris problems, especially after flooding of its watershed.

The Straits of Juan de Fuca and Puget Sound areas have moderate quantities of debris consisting of logging debris, logs, and trees washed down from the watershed. Fairly large concentrations of kelp are found in these areas. The Seattle/Tacoma area has nominally moderate amounts of wood, which can become locally heavy in some locations. Oil spills anywhere in the Northwest could be expected to encounter some wooden debris.

The open waters of the Pacific Ocean have light concentrations of debris, apparently similar to the previously described Atlantic Ocean situation.

The debris concentrations in the nearshore areas of the Hawaiian Islands are light to moderate, consisting of small natural wood and municipal trash in populated areas.

In summary, floating debris is present in some areas of the United States in quantities that have been and will be major impediments to the recovery of spilled fluids. In other areas, the extent of debris effects in spill-recovery operations can vary from being moderate to not being a factor at all. Where debris is present in quantity, the spill-recovery efforts will be more costly and time-consuming than in areas with little or no debris concentration.

The reader is referred to Chapter II for detailed descriptions of debris sources, effects on the location and quantities of debris, and detailed descriptions of local debris situations, including the available debris quantity information for various local areas.

2. Debris-Handling Equipment

One of the primary tasks of the study effort was to conduct a review of current practices in debris-handling equipment and techniques. Practices used both in past spills and in regular programs of waterborne debris removal were investigated. In general, two types of agencies run regular waterborne debris cleanup operations: The U. S. Army Corps of Engineers; and various local, state, and port organizations and authorities.

The Corps operates federally funded projects to remove and dispose of hazardous debris from navigable waterways in Boston, New York, Baltimore, Washington, D.C., Norfolk-Hampton Roads, San Francisco Bay, and Puget Sound. These programs annually collect hundreds of thousands of cubic feet of waterborne debris, mostly wood, through the use of specially constructed debris-collection vessels.

The main local debris-cleanup programs encountered in the study are operated in Long Beach, Los Angeles, Baltimore, and Philadelphia. These programs also use specially constructed debris-collection vessels.

The vessels used for debris collection by both the Corps and the ports are generally of two types--either a self-propelled barge or boat with a front-end-loading wire-mesh basket mounted on the bow, or a self-propelled catamaran-type vessel with chain-link nets for collecting debris slung between the hull sponsons. All of these vessels are designed to operate in protected waters only and are not suitable for open-ocean operation except in very calm conditions.

Information collected concerning past oil spills shows that requirements for debris-handling equipment vary greatly from one spill situation to another. In some cases, notably in open-ocean spills, there is very little need for debris-handling equipment because debris is present in small quantities and tends to be sparsely scattered. In other spills, particularly

those which occur in restricted harbor areas or during unusual storm or flood conditions, the quantity of debris encountered has been orders of magnitude greater than the amount of oil spilled. These cases require massive debris-handling efforts, lasting as long as 3 or 4 months, involving hundreds of individual pieces of debris-handling equipment.

Some of the types of debris-handling equipment used in past spills include

(1) Wire-mesh baskets on articulated hydraulic cranes
(2) Clamshell buckets
(3) Dragline buckets
(4) Debris conveyors
(5) Oleophilic-belt-type skimmers
(6) Front-end loaders
(7) Backhoes
(8) Rakes, shovels, pitchforks, ice tongs, pike poles, and other hand tools.

This equipment has generally been mounted on barges or other vessels of opportunity such as LCU's or LCM's. In addition, vessels used in regular debris-cleanup operations have often been used to help recover debris from oil spills. These vessels have generally been very effective in recovering debris from the water but seem to lack sufficient on-board storage capacity. In some cases, additional temporary on-scene storage has been provided by flat barges or scow barges, 55-gallon drums, cardboard boxes, wooden crates and baskets, plastic trash bags, standard steel trash containers, and the bottoms and decks of work boats.

A list of performance considerations to be used in designing, selecting, evaluating, and recommending debris-handling systems for future use in oil spills was developed. The list includes rate of recovery, sensitivity of equipment to various types of debris, temporary storage capacity, deployment considerations, logistic requirements, cost, versatility, and safety considerations. These criteria formed a basis for the evaluation of current practices and for estimating the effectiveness of equipment from other areas which has not been used in spill situations.

The evaluation of current practices revealed that the shortcomings of debris handling in spills are generally due to nonavailability of suitable equipment which now exists. An observation is, therefore, that major improvements in debris handling in spills can be gained by concentrating on making existing equipment more readily available to agencies responsible for spill cleanup.

In investigating the possible uses of equipment from other industries for debris handling, it was found that there are many promising equipment and technique concepts from industries such as logging, sewage treatment, and solid waste disposal which can be applied to future debris-handling problems. Further research is needed to determine the effectiveness of these kinds of equipment in actual spill cleanups.

A significant result of the study is a definition of the complexity of debris-handling problems in oil spills. The handling problem was subdivided into the following eight general functions:

(1) Containment and/or diversion
(2) Recovery of floating debris
(3) Removal of debris from beaches or shoreline
(4) Temporary storage
(5) Processing
(6) Transfer
(7) Transport to disposal site
(8) Disposal technique.

It is felt that these eight functions accurately describe the various aspects of the debris-handling problem. The equipment requirements are listed by specifying the equipment and techniques most suitable for each function. The needs of a given situation can then be assembled from the various required functions. The reader is referred to Chapter III for further information about debris handling and for detailed recommendations for satisfying functional requirements in various situations.

3. Effects of Debris on Pollution-Response Equipment

The effects of debris on pollution-response equipment determined during the program are listed below, as applied to three general types of response devices.

a. Debris Effects on Containment Devices

Debris has caused physical damage to containment devices during past spill-cleanup operations. The most severe types of failures were ultimate tensile failures of the devices due to debris forces, or the holing of inflatable devices causing them to sink. In these cases, the containment capability was completely compromised. Other types of damage which debris has caused to containment devices include tearing of the fabric, puncturing, and local chafing causing a hole to gradually develop.

Nondamaging debris effects include forced submergence of the containment device due to the weight of debris, lifting due to debris rolling or being forced underneath the skirt, upsetting of trim due to applied debris forces, snagging, and hindrance of deployment.

b. Debris Effects on Spill-Recovery Equipment (Skimming Systems and Transfer Systems)

Destructive effects of debris on recovery equipment in past spills include breaking of mechanical components of the equipment caused by snagging or impacting of debris with exposed machinery, tearing of exposed sorbent belts or disks, and sinking or holing of the devices due to impact with heavy pieces of debris.

Nondestructive debris effects include debris buildup at skimmer intakes causing oil to be diverted around the intake; forced submergence of smaller recovery devices; upsetting of trim; recovered-debris weight changing the displacement of the device; accumulations of smaller debris clogging reservoirs; smaller pieces of debris jamming mechanisms (without damage); clogging of transfer system intakes; seizing of rotating pumps caused by

ingestion of plastic or plastic sheets; and the stoppage of diaphragm-type pumps by long, thin pieces of debris.

c. Debris Effects on Auxiliary Equipment

Destructive effects of debris on auxiliary equipment have included impact of large debris causing damage to hulls, breakage of propellers, and puncturing or tearing of fabric storage vessels. Other debris effects--such as impairment of navigation and maneuverability, fouling of propellers and water intakes, upsetting of vessel stability (thereby impairing personnel safety), and reducing fluid capacity of storage vessels--have also occurred during past spill cleanups.

Detailed discussions of the effects described above are contained in Chapter III of this report, entitled Effects On and Protection Of Pollution-Response Equipment From Debris in Oil Spills.

4. Anti-Debris Design Features and Techniques

Some of the design features and techniques used to protect pollution-response equipment from debris effects are described below by type of equipment.

a. Containment Devices

Many containment devices have features which make them relatively tolerant to debris-contact effects. Some designs use tensile members or reinforced fabric for tensile strength. These designs are most able to withstand the impact of large debris. The reinforced fabric design also provides resistance to puncturing, tearing, and chafing. Other designs use coatings over the fabric to provide puncturing, tearing, and chafing resistance. Some designs have smooth surfaces on the spill side of the barrier which reduce snagging. Some have added righting moment and reserve buoyancy capability to better resist debris upsetting forces.

Techniques used to reduce or eliminate debris effects on containment devices include the use of two barriers, thereby preventing debris from coming in contact with and damaging the primary containment barrier; using barriers for diversion of debris in currents, rather than for containment, thereby reducing debris impact forces; using manual or mechanical tending and debris handling to eliminate or minimize debris contact with the barrier, and using permanent debris fences to keep oil-spill-prone areas clear of major debris concentrations.

Temporary and permanent repair techniques have also been developed to repair containment devices damaged by debris. The quick repair of damage reduces damage effects on the overall spill-recovery operation efficiency.

b. Recovery Equipment Skimming Systems

Skimming-system design features intended to reduce debris effects include use of trash screens to keep debris out of the skimmer inlet; shielding of mechanical parts to prevent jamming by small debris; isolation of machinery from contact with debris and resulting damage; and the use of debris-handling systems, such as debris belts, to remove debris from the vicinity of the oil-recovery mechanism.

c. Recovery Equipment Transfer Systems

Design features used on some recovery-device transfer systems to minimize debris effects include use of large-diameter hoses and fittings to minimize clogging by debris, use of quick-disconnect fittings for ease of cleaning or replacement of components, and inclusion of the capability to backflush the system to be capable of unclogging the system without disassembly.

d. Auxiliary Equipment

Design features used to minimize debris effects on auxiliary equipment include use of heavy-duty propellers or propeller guards, use of jet-drive propulsion units, and use of heavy-duty hull construction.

Each design feature or technique mentioned above is used with or on some types of equipment but not on others, depending on patent situations, availability and cost of labor, funds available for initial expenditure for equipment procurement, local ocean environment, and the type and variations of local debris situations. In general, most of these features and techniques have evolved locally or regionally over a period of years depending on the specific experience of local equipment manufacturers and cleanup contractors.

Recommendations of design features or techniques for protection of pollution-response equipment from debris effects consist mainly of selections from the current practices given above. To avoid repetition, these recommended practices and design features are not repeated here. The reader is referred to Chapter IV for further detail.

D. CONCLUSIONS

(1) Most of the man-made debris (by weight) that is found in the areas of interest of this study is wood. This wood may be natural or cut wood, or a combination of the two, depending on location.

(2) Open-water, man-made debris concentrations are very sparse, with the exception of the Northwest United States. The open-water debris in the Northwest is mainly logs and logging debris that is driven out to sea.

(3) A major source of debris in the New York, Boston, Baltimore, Norfolk, and San Francisco port areas are the old, poorly constructed, wartime shorefront structures, which have decayed into the water. These older ports generally have the worst man-made debris quantity problem.

(4) Rivers carry far more debris during floods than other periods because of the increased water levels that occur, along with the destructive

action of the storms that cause the flooding. These factors cause much more wood to be floated into and transported by rivers during flood periods.

(5) A great many derelict structures and vessels are present in several port areas. These abandoned items are generally wood and are a major source of floating debris.

(6) Debris concentrations within a region depend greatly on local currents, winds, and geographical factors. The areas where debris concentrates and the quantity in these areas are therefore very local in nature within a region.

(7) The recent awareness of the public with respect to pollution of waterways has resulted in legislation which is reducing the debris problem nationally. Containerization of cargo is also reducing the input of debris into harbors considerably due to the discontinuation of dockside unpacking of cargo.

(8) Very large quantities of marine growth are present in the areas of interest of this study. This growth could cause severe problems when cleaning up large spills.

(9) Port debris-cleanup operations currently under way do not completely remove the debris present in those areas. Enough wood remains to hamper spill-cleanup operations.

(10) The complete containment of spills with barriers in areas where debris sources are present is desirable to reduce the amount of debris entering the spill.

(11) Mechanized equipment, in general, has been observed to be less expensive than manual labor for handling debris. The use of equipment where ever possible to replace manual labor will have a positive effect on reducing spill-recovery costs.

(12) If the spill cannot be contained in a current by artificial barriers, diversion of the spill into calm water reduces the difficulties of handling debris in strong currents. The diversion of the spill into calm water is, therefore, desirable where possible in river and bay spills where strong currents are present.

(13) Handling equipment not currently used in spills may be useful in improving spill-cleanup efficiency by replacing some tasks presently performed by manual labor.

(14) Major improvements in debris-handling efficiency in spills can be gained by making existing construction and agricultural equipment more readily available to agencies responsible for spill cleanups.

(15) Many situations exist, such as environmentally fragile sites or sites where waterborne equipment cannot maneuver, where the use of mechanical equipment for recovery is difficult or impossible. In these locations the use of manual labor is the only acceptable alternative for recovering debris.

(16) Ultimate disposal of oil-soaked debris has been a severe problem in past spills where burning was prohibited by air-pollution regulations. In these situations, the location of acceptable landfill sites and transportation of the debris to these sites have been major efforts.

(17) Most debris-handling shortcomings in past spills have been due to the nonavailability of equipment rather than the functional deficiencies of present equipment. These shortcomings have mainly occurred in spills away from industrialized areas, where heavy equipment was not available.

(18) Present barrier designs are marginally adequate or inadequate for containment of debris in high tidal or river currents. The forces developed will fail many barriers or upset, sink, or submerge others, destroying their oil-containment capability.

(19) In many past circumstances, containment devices have been used to contain large amounts of debris in relatively strong currents. Very little knowledge concerning the forces developed in the containment devices in these situations exists.

(20) All commercially available containment devices are designed primarily to contain oil. No currently available barriers have been specifically designed to contain debris.

(21) Current available recovery-equipment designs have more design features for minimizing or eliminating debris effects than do containment devices.

(22) No currently available recovery devices can recover oil and debris effectively in large quantities of heavily concentrated debris. The

devices' skimming performance or their inability to handle the large quantity of debris restricts their performance in these situations.

(23) More widespread application of presently known design features and protection techniques could greatly improve spill-recovery efficiency where debris is present.

E. RECOMMENDATIONS

(1) The Coast Guard should initiate or become involved in joint debris-oriented programs with the Environmental Protection Agency, the Corps of Engineers, and the Navy. This would help to eliminate overlapping efforts by these organizations. Since there is much common interest and activity in debris-related areas, a coordinated debris effort would be in the best interests of all concerned.

(2) The use of aerial surveillance should be considered to identify and monitor local areas where specific debris concentrations exist. Trends could be established and the effects of source removal programs evaluated. Planning for pollution-response equipment regional deployment would also be facilitated by having up-to-date debris quantity information for these debris-prone areas.

(3) Lists of locally available debris-handling equipment should be included in regional contingency plans to allow on-scene commanders to become aware of the local resources available for handling debris.

(4) Requirements for and local sources of debris-handling equipment should be established if detailed local debris-quantity information becomes available for areas prone to large oil spills. This information could be included as part of a larger regional response plan for large spills.

(5) Local sites for ultimate disposal of oil-soaked debris should be pre-established in areas where debris is found in appreciable quantities. This would eliminate the problem in locating a local disposal site after a spill has taken place.

(6) The further exploration of the feasibility of on-scene processing of debris to facilitate storage, transfer, and disposal should be

investigated. If this is found to be feasible, spill-recovery efficiency could be greatly improved.

(7) The exploration of further development of on-scene disposal devices, such as controlled burning techniques, should also be investigated. If feasible, this disposal method would provide an even greater increase in spill-cleanup efficiency than the use of on-scene debris processing. If the air pollution problem could be solved, this appears to be the most economical and efficient method for disposing of oil-soaked debris.

(8) The Coast Guard should consider joint purchase of debris-handling equipment with other organizations interested in debris recovery. This would minimize initial equipment capital expenditure and operating costs. The Corps of Engineers, especially, has similar requirements in the debris-handling area.

(9) The typical forces developed in containment systems when debris and currents are present should be investigated to allow comprehensive containment-system design. Containment systems could then be rated for use in particular types of debris situations.

(10) The determination of typical forces developed when large debris impacts skimmers should be determined to allow skimmers to be designed so as to be capable of withstanding these impacts. Skimmers could also be rated for use in various debris situations.

(11) Design guidelines to improve resistance of pollution-response equipment to debris effects should be developed to allow a useful specification for equipment to be used with debris to be generated. This would allow procurement of debris-compatible equipment in areas where debris is a problem.

(12) A standard debris-barrier design to be used on-scene for debris containment should be developed to eliminate some of the containment failures that currently take place in spills where debris is present. This barrier design could be either purchased beforehand or fabricated on site by the spill-cleanup personnel.

(13) Mechanical behavior of debris contained behind a barrier in a current should be investigated. This would allow better containment barriers for debris to be developed. Optimal designs for containing both debris and oil could also be developed with this knowledge.

(14) Factors affecting transfer-system performance in spills with debris should be evaluated in depth. These factors would include viscosities of fluids to be pumped, pumping-head requirements, velocities developed in the system, the amount of oil/water mixing that takes place, and the tolerance of the particular system to debris. Including debris effects in the evaluation of these other considerations would allow the selection of optimum systems for the situation rather than just the optimum system for debris tolerance.

CHAPTER II. DEBRIS

A. INTRODUCTION

One of the major subtasks of the program was the investigation of types, sizes, and quantities of debris which are or could be expected to be encountered in oil-spill situations on the navigable waters of the United States. This subtask involved the determination of what debris has been found mixed with oil spills in the past and also, to the extent possible within the program constraints, the determination of what typical debris situations exist at various times in the geographical areas of responsibility of the Coast Guard. The effects of various environmental, physical, and geographical factors on debris situations were also investigated.

This debris investigation resulted in a list of generic types of waterborne debris, a set of general categories which describe the various types of debris with respect to their engineering properties, an appreciation of local debris situations around the United States, and an understanding of the sources of waterborne debris.

B. GENERAL OBSERVATIONS

During the course of this study, several general observations concerning debris became apparent.

1. Oil and Debris Tend to Gather in the Same Location

An observation that is almost universal when oil or other spilled fluids are on the water in a near-shore or harbor area is that any substance floating on the water before the spill will, if left alone, become mixed together with the spilled substance. This happens because the same current and wind forces that drive the spilled fluids in one direction or to one location will also tend to push loose debris in the same direction or to the same location. If the prevailing currents and winds drive the

spill against a shoreline, containment boom, seawall, or other barrier, the debris that is already collected against the barrier will be thoroughly mixed with the spilled fluid. Also, additional debris that is on the water will be driven to the same location and will ultimately wind up in the spill-cleanup operation.

In areas where strong tidal actions take place, a situation similar to that described above occurs. When the tide is either flooding or ebbing, the rips which take place in the tidal zone collect much of the floating material and hold it in a line. This floating material is apparently driven into the rip zone by wind which blows in a heading different from the main current directions. If a spill takes place in one of these areas, the spill can be and usually is blown into the same rip zones if not immediately contained. The local current action then thoroughly mixes the debris and oil.

In open-water spills, where there are no local current interactions or natural fixed barriers on which spilled material and debris can collect, the extent of debris and spill mixing is less severe than in cases where a natural or man-made barrier is encountered. If containment booms are used to control an open spill, however, some of the debris will be driven by the wind or current and will collect against the boom. Also, if the spill takes place in areas where there is natural marine growth that is fixed to the bottom (such as kelp beds), the spill may be driven into that growth. A natural barrier would thus be created, against which any additional debris would collect and greatly complicate the recovery of the fluid that was mixed with the growth.

2. Experience With Open-Ocean Spill Cleanup Is Very Limited

Most of the spill operations that have taken place to date have been in sheltered waters or have been essentially shore-based operations where a minimum of on-the-water recovery effort took place. Knowledge of techniques and equipment for handling debris on the open ocean is, therefore, very limited.

3. Spill Residence Time Affects the Quantity of Debris That Will Be Found

Generally, the longer a spill is on the water, the greater the quantity of debris that will be trapped with it. This is especially true for areas where debris is found in heavy concentrations. If the spill is in a current zone and is contained by a boom, of if it is driven into an intertidal zone, the quantity of debris that will come in contact with the spill will increase as the time of residence of the spill increases.

4. Very Local Conditions Have Strong Effects

A factor observed in many past spill situations in which debris was a consideration was that the magnitude of the debris problem can vary greatly from place to place in any general area. The amount of debris encountered may vary orders of magnitude in as short a distance as 50 yards, especially in harbors. Certain parts of a harbor will, under the right current and wind conditions, act as collectors for floating objects while immediately adjacent areas remain free of debris. (This situation will be discussed by local area in the Regional Debris Descriptions section of this chapter.)

5. Oil-Herder Compounds Tend to Concentrate Oil Around Debris

Several individuals contacted during the study observed that when oil herder is used on a slick where debris is present, the herder tends to concentrate the oil around the pieces of debris. This phenomenon makes the recovery of scattered oil slicks more difficult by entrapping any debris.

C. DESCRIPTION AND CATEGORIZATION OF DEBRIS TYPES

1. Alphabetical Listing

One of the major goals of the program was to determine the types of debris that are found on the water. Appendix D contains an alphabetical list of the various debris items that have been reported as found floating in the areas covered by this study. In this list (and throughout this report) marine growth such as kelp, eel grass, and other seaweeds is considered floating debris, as its effects on debris-handling and debris-protection activities are similar to those of other forms of debris.

Appendix D makes no comment on quantity or location. These subjects are covered in a following section, entitled Regional Debris Descriptions. Note that there are undoubtedly additional types of waterborne debris which are not mentioned. However, the list provides a relatively thorough source of information regarding the predominant types of debris that are found.

2. Debris-Type Categorization

Most of the individual debris types listed in Appendix D have common properties with other types. Thus, similar types have been grouped into common categories for discussing debris-handling, temporary-storage, or protection techniques.

In selecting categories, the following general factors were considered:

(1) Overall size
(2) Number of principal dimensions (one, two, or three)
(3) Mechanical strength (flexible or rigid)
(4) Integrity (or lack of integrity) of individual item.

The various debris categories are described below. The properties of the category that make it unique are given under each category heading. Types of debris that fall within each category are listed in Appendix E.

a. Category I. General Wood Items

Individual pieces of wood are such a predominant type of floating debris that they have been assigned a separate category. However, pieces of structures, boats, parts of boats, boxes, and other items fabricated from wood may be listed in other categories (such as rigid shapes) if they fit that categorization more aptly.

This category has been assigned Small, Medium, and Large size subcategories. Small wood objects are classified as pieces with no dimension greater than 12 inches. This 12-inch dimension is arbitrary and was selected to provide a subcategory that could be considered handleable manually by one man with a pitchfork, shovel, or hand skimmer. This size distinction is also convenient for simple protection techniques.

Medium wood pieces have at least one dimension greater than 12 inches but less than 6 feet. This size was selected to provide a subcategory describing pieces of wood that need to be handled with small machinery or by more than one person and that are capable of causing impact damage to skimmers. This subcategory also describes a size which can be protected from or handled by pollution-response equipment using manual tending protection techniques.

The Large size category lists objects with one or more dimensions greater than 6 feet. Objects in this category require special handling or pollution-response-device protection techniques due to their large size and weight.

As a general note, all of the material in this category falls into one of two classes--natural wood or processed wood. Natural wood consists of trees or pieces of trees which have not been cut to shape. Processed wood is either dimension lumber (such as 2 x 4-inch boards) or logs that have been cut and trimmed (such as telephone poles, pilings, and logs being shipped to a lumber mill).

b. Category II. Non-Rigid Shapes

Non-Rigid Shapes is a category which describes objects which have the following properties:

(1) Are discrete, individual objects

(2) Have no rigid surfaces (are somewhat pliable)

(3) Have enough integrity to be handled as one piece.

Examples of objects in this category are dead birds, animals, or fish. Because few items of very small size are found which fit this category, the subcategories in this section are Small and Large.

The Small subcategory includes individual objects which weigh less than approximately 20 pounds. Objects in this category can be handled by one man without assistance and would have a minimal effect on skimmers and barriers.

The Large subcategory includes objects whose weight is greater than 20 pounds. These articles would require the use of more than one man or the use of machinery when handling and, due to their weight, could affect pollution-response equipment.

c. Category III. Rigid Shapes

This category lists articles that are discrete, individual pieces and are composed of a solid material which has some inherent strength. Examples of objects in this category include crates, life rings, pieces of household furniture, and rigid plastic parts such as toothbrushes.

Size subcategories of this category are Small, Medium, and Large. Small articles have no dimension greater than 3 inches. This size can cause clogging of pumps and transfer lines on pollution-response equipment and can also be handled manually using a shovel or hand skimmer.

Medium sized articles are those with one or more dimensions greater than 3 inches but less than approximately 6 feet. This sized article could require more than one man for handling and is of the size and weight which can cause mechanical problems to the pollution-response equipment.

Large sized articles are pieces with one or more dimensions greater than 6 feet. Pieces in this category would require large, mechanized equipment for handling and could cause severe damage on impact with some of the pollution-response devices.

d. Category IV. Flexible Sheets

This category of debris is classified as follows:

(1) The item has a surface with a thickness which is at least an order of magnitude smaller than either long dimension.

(2) The material of the item is flexible.

Examples of this category of debris are plastic bags and sheets of paper.

The subcategory distinctions within this category are Small and Large. Small pieces are typified as having no dimension greater than 2 feet. The 2-foot size is estimated to be the largest sheet that will enter pump inlets or suction hoses of recovery devices. Large items are typified as having one dimension greater than 2 feet. Handling problems of material in this category are minor due to their light weight and the capability of compressing the piece into a smaller volume.

e. Category V. Rigid Sheets

Debris in this category is classified as having two long dimensions and one short dimension and being made of rigid material. Debris items in this category include pieces of fencing, plywood, and bark chips. Most items in this category are either cut wood or some piece of a wooden structure.

The subcategories are Small, Medium, and Large. The dimensional limits of the size of the items in these subcategories are the same as those used for Category III (Rigid Shapes). As before, the Small subcategory items would be a problem in clogging pumps; the Medium would require special handling; and the Large could severely damage pollution-response equipment and could cause handling problems due to their size and weight.

f. Category VI. Amorphous Material

Items in this category include materials that cannot be handled as solids due to the lack of any inherent strength. An example of material in this category is grease. Both the handling of and the protection from this category of debris involves the same general problems as those found in the primary spill recovery operation. A possible problem in picking up this category of debris may be that oleophilic-belt- and drum-type skimmers would be unable to recover materials such as grease or wax. If that is the case, the grease debris on the water (especially if large amounts of material are involved) can have a significant effect on oleophilic recovery devices. Handling considerations are also a problem due to the material's fluid-like properties. Since the debris in this category has no particular shape, no size distinction can be applied. There are, therefore, no subcategories given for this category.

g. Category VII. Filamentous Pieces

Debris items in this category are characterized by having a length dimension which is considerably longer than the cross-sectional dimensions. The material of the individual pieces is flexible and may or may not have any appreciable breaking strength.

The subcategories for items in this category are Individual Pieces and Groups of Pieces. Individual pieces are items which are found alone and can be handled one discrete item at a time. Groups of Pieces are groups of multiple pieces which, in a practical situation, are difficult to separate. Examples of debris that falls within this category are kelp, fishing line, and cellulose fibers.

h. Category VIII. Special Cases

This category lists debris types that are either unique with respect to physical characteristics and therefore do not lend themselves to general categorization, or those that have some physical property which

makes their recovery or handling considerations a special problem. General subcategories in this category are:

(1) Items With Circular or Spherical Surfaces

(2) Fabricated Paper Items.

The subcategory of Items With Circular or Spherical Surfaces is included in this category because these items cannot be recovered by belt- or drum-type skimmers due to their tendency to roll. They also are very difficult to recover using clamshell and other similar types of crane attachments due to the same tendency. Items in this subcategory include tennis balls, bottles, and cans.

The subcategory of Fabricated Paper Items is included because the shapes in this category do not have appreciable strength. Each of these items is paper which has been treated with wax to provide a liquid seal along with some minimum strength. Items in this subcategory can be crushed to reduce their volume and would have a minimum damaging effect on pollution-response equipment. An example of an item in this subcategory is a milk carton.

D. DEBRIS SOURCES

It is beyond the scope of this study to describe the type and quantity of debris to be found in every local situation. This section is intended to provide general information about sources which would permit prediction of debris problems in a particular local area if the types of sources in that area were known.

1. Metropolitan-Area Sources

Debris enters near-shore waters of many areas of the United States due to the activities of the concentrations of population that exist in those locations. In general, the denser the population in the near-shore area, the greater the amount of debris input to the water in that location.

Following are listings of the various metropolitan-area sources of floating debris:

a. Sewage

Many areas of the United States, at the time of the writing of this report, discharge raw sewage into coastal waters. (It is noted that the magnitude of floating material discharged from this source is decreasing rapidly due to various Federal and state pollution-abatement activities.) Items such as plastic bags, cigarette filters, rubber bands, pieces of solid plastic, pieces of paper, condoms, rags, floating grease, and wax are commonly discharged in this sewage. The quantity of floating material from these sources can be appreciable in areas where a great deal of local discharge takes place.

b. Storm Drains

Storm drains, especially in areas where no rainfall occurs during certain seasons of the year, collect debris that has been discarded in the streets. When flooding occurs, the storm drains fill and this collected material is washed out the storm-drain discharge. Debris from storm drains includes pieces of wood, branches, baseball bats, dead animals, cardboard boxes, toys, paint cans, paint brushes, plastic sheeting, paper, shoes, articles of clothing, rubber thongs, plastic items, and every kind of ball used for recreation in the city areas.

c. Dumping

Many municipal areas which border on waterfronts have a significant debris input from dumping activities. Individuals, businesses, and ship cargo loading and unloading are all responsible for debris inputs from this source. The debris is dumped both directly into the water and into tributaries which lead into the waterway. Almost any item that will float and that is used in metropolitan areas can enter the water from this source. Examples of commonly found items are automobile tires, household

furniture, luggage, and crates of various types.

2. Commercial and Industrial Debris Sources

Certain commercial activities along the near-shore area cause debris to enter the waterways.

a. Logging

Commercial logging activities create debris in two ways: Material, such as branches and stumps left in the hills after logging activities in an area take place, is washed out of the watershed during storms and enters the water; and transportation of logs by rafting contributes large quantities of bark chips and logs which escape into waterways. The quantity of material which enters the waterways from these activities is especially great in the Northwest United States.

b. Shipping Activities

Shipping activities generate debris in many locations nationwide. The type of debris generated is of two types-- dunnage material accidentally or deliberately dumped overboard during loading and unloading operations, and cargo lost during transfer. Dunnage material consists of pieces of wood, pallets, timbers, paper, sheet plastic, and other material used for cargo protection. Lost cargo that floats includes items such as grain, hemp, fruit, wood chips, cork, plastic, resin beads, and cloth. It is noted that the quantity of material from these sources in some port locations is decreasing rapidly due to the increased use of containerized cargo methods which involve no uncrating and unpacking at the dock.

c. Polluting Industries

Many industries around the United States discharge floating material into the navigable waterways. Currently, this source is present but

is a contributor of only minor quantities to the nationwide debris situation. Also, the quantity of debris from this source is becoming smaller due to the increased Federal and state efforts to curtail this type of pollution.

d. Construction and Shipbuilding

Waterfront construction in some areas contributes wooden debris to the water. Scrap lumber, boards, trim ends of pilings and timbers being cut to length, and other wooden debris can enter the water near construction projects. Litter, such as large plastic sheets used to cover lumber, lunch trash (plastic bags, paper bags, cans, and bottles) from the construction crew, can also be found in fairly large quantities near a large construction project. Shipbuilding activities contribute wood and rope to the waterfront, mainly during ship-launching activities. Wood used for shoring and bracing is discharged to the water when a ship is launched. Material that is on the decks of recently launched ships is sometimes discarded overboard when the ship is outfitted. This can include wood from crates, rope, plastic sheeting, rubber hoses, and paper. The same type of debris can also be introduced into a harbor when drydocks are flooded.

3. Special Problems With Harbors and Ports

Many of the larger ports of the United States have within their boundaries derelict vessels and abandoned or decaying wooden waterfront structures. In some areas these vessels and structures contribute a great deal of wooden debris. The estimated quantity of debris produced from these sources will be discussed in the Regional Debris Descriptions section. Types of wood produced from these sources include large items, such as pilings, timbers, beams, and ship masts; medium-sized pieces, such as boards, boat transoms, and pieces of deck; and small items which are mainly pieces of the larger items. Most of the derelict vessels which contribute debris are of pre-World War II manufacture and have been abandoned at anchorages due to their obsolescence or deteriorated state. The waterfront

structures which contribute wood can be of more recent origin, although a great many are wharfs and docks that were built temporarily for World War II use. In general, the quantity of both derelict vessels and structures is greater in older port areas.

4. Rivers

Rivers provide a source of debris to many of the offshore areas of the United States. During normal flow stages, rivers mainly pick up wooden material from their watershed along with some municipal debris from cities located upstream of the ocean. Larger rivers, such as the Mississippi and the Columbia, also gain some debris from the commercial activities that take place on them.

The greatest amount of debris in rivers is present during and after periods of severe flooding. The floods cause the river to rise above its normal level, and many areas that are normally dry are flooded and washed out due to the increased water level. Large quantities of debris (mostly wood) are present in these normally dry areas. This material is floated with the high water and is washed downstream. In addition to the high-water washing, periods of flooding often take place after hurricanes or other severe storms. These storms create much debris that enters the river and is washed downstream. The concentration of debris introduced by the rivers is greatest in estuary areas or, in the case of very large rivers, in the bays into which the rivers discharge.

5. Boat and Ship Debris

Some significant debris enters harbor and near-shore areas from boat and ship activities.

a. Fishing Vessels

Both commercial and sportfishing boats contribute debris to offshore areas. Debris from this source is mainly discarded packaging waste

from food and beverages consumed aboard these craft. Items discarded to the water include plastic bags, cans, bottles, cartons, plastic six-pack holders, paper cups, paper, and some wood from crates. Occasionally fishing line, nets, floats, and rope are discarded or lost. The quantity of debris from this source which could be expected in an oil spill is very small, as debris from these vessels is generally discarded well offshore, and the material disperses rapidly.

b. Cargo Vessels

Cargo vessels contribute debris from both crew activities and lost cargo and dunnage. The crew wastes discharged from ships are generally the same as previously described for fishing vessels. The quantity of debris from discarded crew waste is relatively small and usually is found on the open ocean; it has little effect on debris in oil spills. Loss of large-sized cargo overboard usually occurs in severe storms when deck cargo is washed overboard. Loss of large, buoyant items could be expected in this manner. Cargo and dunnage losses during loading and unloading operations have been previously discussed in the Commercial and Industrial Debris Sources section. Debris created by dunnage losses at sea can be appreciable. In some cases, deck cargo is uncrated before entering port to facilitate unloading. The wood used to brace and package the cargo is discarded overboard. Other dunnage material entering the water in this manner includes large plastic sheets and line used to cover deck cargo such as lumber.

c. Military Vessel Operations

Some debris, mainly food packaging wastes, is lost overboard on military vessels. Apparently a significant concentration occurs dockside only when milk cartons, plastic and paper wrappers, cans, and bottles are continually discarded by the crew. The material tends to collect alongside the ship or underneath the adjacent docks. The quantity of debris produced by this source would only be of significance in small dockside spills.

d. Recreational Vessels

Debris produced by recreational vessels is mainly food and beverage packaging waste and paper plates, cups, and napkins. The local debris concentration from this source in harbors, marinas, and bays where a great deal of pleasure-boat activity takes place can be significant. Some of the more populated marinas can have debris covering the water in corners of slips so that it creates a problem in small oil spills. Other less numerous debris items attributable to recreational vessels include life rings and preservers, articles of clothing, rubber shoes, pieces of wood, lengths of line, paint cans, and paint brushes.

e. Shipwrecks

Shipwrecks can provide a dense local source of debris in a spill. Any buoyant material, such as life rings, loose wood, insulation, plastic sheets, cargo lighter than water, life rafts, life boats, drums, boxes, some canned goods, crates, etc., can float off a wreck. Since the source of spilled oil in many spill situations is a sinking or sunken tanker, the debris listed above will enter the water with the oil. Buoyant cargo can be a problem in recovering a spill due to the potentially large quantity of material present. Ships carrying large amounts of small buoyant items can present a severe situation in which a great deal of small floating material could become mixed with the oil. Some cargoes which could cause this situation in a spill are resin beads, small plastic items (pens, toothbrushes, etc.), animal pelts, grain, hemp fibers, paper, rope, wood chips, fruit, empty cans or cartons, wood items, automobile tires, toys, and cloth items.

Another problem which has occurred in some spills involves debris within partially-flooded ships. If oil inside a stranded or foundering ship must be removed, the situation is greatly complicated by the flotsam within the ship. Some typical items found floating inside a ship include cans, bottles, clothing, rags, furniture, cushions, papers, cork, pens, and wood.

6. Seaweed, Kelp, Eel Grass, Etc.

Because of the potentially large quantities, marine growth can become a severe debris problem in a spill situation. The material can become involved either by the spill being transported into natural beds or, in the fall and spring, by dead material being driven into the contaminated waters. Also, in some areas such as the Northeast, a combination of both situations can occur where the contaminant kills the kelp or eel grass causing it to float out of its beds and to become mixed with another portion of the spill. The quantity of debris which enters the spill from this source can be very large, especially in areas of extensive kelp beds or abundant eel grass. The situations found in the various areas of interest of this study are discussed in the Regional Debris Descriptions section.

E. NATURAL EFFECTS ON DEBRIS SITUATION

Certain natural factors can affect the location, type, and quantity of debris in local situations. Some of these factors, and their effect on local debris situations, are covered in the following paragraphs.

1. Seasonal Effects

A number of seasonal variations can affect local debris concentrations.

a. Spring Thaws

Spring thaws in many locations raise levels in downstream waterways and also release debris that has been trapped by ice and snow in watersheds. Both these factors can cause gradual but pronounced increases in debris concentrations in downstream tributaries in the spring. The reader is referred to the previous section on rivers as debris sources for a discussion of the effect of higher water level on debris in rivers.

b. Seasonal Rainfall

Increased rainfall due to the onset of a wet season, especially in areas that are dry much of the year, can bring much stranded debris material into natural waterways and ultimately into the ocean. This effect is similar to that described above in that it occurs gradually and increases the nominal debris level in rivers, estuaries, and ultimately in some offshore areas.

c. Annual Defoliation

Annual fall loss of leaves by trees and dying of annual plants can cause locally heavy concentrations of these materials in some areas of the United States. This effect is most pronounced in the Northeast and Mid-Atlantic near-shore areas and occurs for a short time period only.

2. Storms

Storms, especially severe ones such as hurricanes, can cause sudden peak debris inputs to various areas. The following individual factors all contribute to this increase of local debris level:

a. Increased Water Levels in Rivers and Tributaries

Severe storms can discharge large amounts of rainfall to a watershed area in a short period of time, as has been discussed previously. The resultant swelling of creeks and rivers brings down material normally stranded above high-water level. Also, in areas where surface water is present only during storms, the water will flush out any debris present in the normally dry waterways. The debris produced from the above effects mainly enters the water during a short period of time rather than the more gradual increase due to seasonal changes.

b. High Winds

The high winds of a storm can cause whole trees, branches of trees, and parts of decaying structures and vessels to enter the water. This effect is normally combined with high water in causing a peak debris-load increase in a given area.

c. High Tides and Area Flooding

High water levels during storms cause debris normally stranded to come off of beaches and river banks. Also, during especially severe flooding, many populous areas can be inundated and houses, roofs, front porches, automobiles, chicken houses, wagons, dog houses, trees, fences, and many other large items can be brought into the waterways.

d. Severe Wave Activity

Large waves associated with storms can cause destruction of shorefront structures. Material from these structures can include wooden timbers, boards, pilings, and parts of houses. This debris generally stays floating in the shorefront area or is driven ashore.

3. Tides and Currents

a. Extremely High Tides

Extremely high tides have the same general effect as previously described under the High Water Levels section except that the high tides work mainly on material stranded on shore. The effect in some areas can be much more severe than high water in rivers, due to the quantity of material that is floated off. Some areas, such as San Francisco Bay and New York Harbor, have many miles of shoreline covered with debris normally stranded above high-water level. During severe flood tides, a large percentage of this material is refloated onto the water.

b. Tidal Currents

Tidal currents have an effect on locations to which debris is transported. In some areas where fast tidal currents occur, these currents (when running) can be the predominant factor in the transport of debris. As was previously described in the General Observations section of this chapter, debris can be concentrated in tidal zones along current convergence lines.

4. Wind Direction

Wind direction can affect both the concentration of debris on the water and where the debris is found. If, in a near-shore area, the wind blows predominantly in one direction and currents in the area are weak; the debris that is on the water will tend to be driven into one location and concentrated. If the wind then shifts direction, the concentrated material can be blown out into open water and, given enough time, concentrated in some new location. The location of natural traps for debris, therefore, will depend on the prevailing wind condition.

5. Debris-Concentration Effect of Geographical Features

Local geographical factors can greatly affect where and in what quantity debris is found in a region. The following section discusses typical local areas where debris is found in large quantities relative to open-water concentrations.

a. Calm-Water Areas

Debris in near-shore areas, if left alone, tends to be ultimately transported by wind and current forces to areas of relatively calm water. These areas include the following:

(1) Coves

(2) Bays

(3) Certain sheltered sides of harbors or estuaries

(4) Underneath and around docks, piers, and ramps

(5) Behind or on small islands

(6) Behind locks or dams

(7) In or around concentrations of kelp, seaweed, or marsh grass.

These calm-water areas tend to have the greatest concentrations of floating debris in a given region, the exception occurring with unusual wind conditions. Most of the debris in a shoreline or harbor spill could be expected in these areas.

b. Free-Floating Concentrations

As has been previously discussed, tidal rips or areas where river and tidal currents interact tend to provide lines of stagnant surface water in which lines of debris collect. The quantity of debris in these lines, in areas with strong tidal action, is usually far greater than occurs in other open-water areas.

6. Effect of Tidal Flushing Action on Debris

Harbors and bays which do not have a good natural flushing action due to tidal currents, tend to have more debris than other areas with the same relative debris input and good tidal flushing actions. If no general flushing action is present, debris material will be transported back and forth locally by tidal action but will not be carried out of the area.

7. Tidal Waves

The West Coast of the United States and Hawaii can be subject to periodic tidal waves caused by earthquakes. The extremely high water level

present when a tidal wave strikes a harbor or coastal area causes the same general type of effect as storm waves and flood tides, only with much more severity. Large-scale destruction of shorefront structures can occur with the resulting generation of a great quantity of debris.

F. REGIONAL DEBRIS DESCRIPTIONS

The following section discusses the type and quantity of debris found in selected harbors, estuaries, and coastal waters of the United States. To the extent possible within the scope of this effort, local debris conditions and factors which affect those conditions are also discussed.

The regional areas discussed are shown in Figure 1. As was mentioned in the introduction, the areas considered in this study were the coastal areas of the continental United States and Hawaii. Rivers, the Great Lakes, Alaska, and Puerto Rico were omitted.

Detailed regional descriptions of the debris situations determined during the study are listed in Appendix F. A summary of that information is given in the following Table 1.

The regional descriptions in Appendix F are broken down into discussions of debris situations that occur in local areas. Each area discussed has certain particular debris types and quantities which make that area unique. In general, harbor areas, especially around large centers of population, are different from adjacent offshore or coastal situations and are, therefore, listed as separate areas.

The area discussions in Appendix F are listed according to debris category. Descriptions of items found in the various categories; and, where information was obtainable, estimates of the quantity of debris in the predominant General Wood Items and Filamentous Pieces categories are given.

It is also noted that the descriptions given in Table 1 and Appendix F are of debris situations that existed in 1973. The debris types and quantities in any area can and will change. Factors which can and are drastically affecting the type and quantity of debris found in an area include

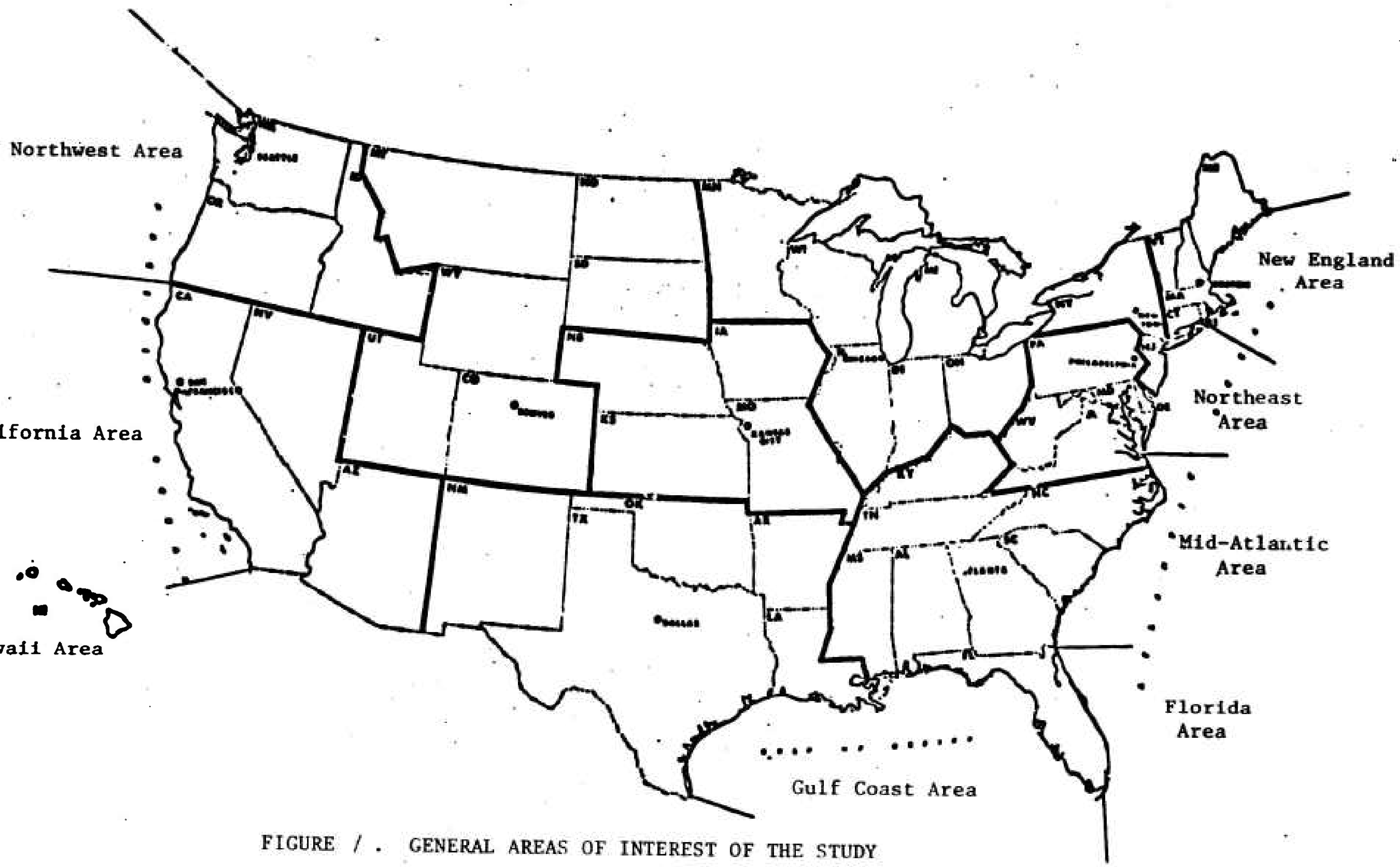


FIGURE / . GENERAL AREAS OF INTEREST OF THE STUDY

TABLE 1. DEBRIS INFORMATION SUMMARY

Region	Area	Debris Situation
New England	Coastal	Some natural wood floating on the water; collections of wood on the beaches; large amounts of eel grass, marsh grass, and seaweed. Quantities of debris increased somewhat by severe storms.
New England	Boston/Portland/ Providence	Large quantities of man-made wood drift from decaying structures and vessels; some seaweed, eel grass, etc.; some municipal trash.
Northeast	New York Harbor	Severe man-made wood problem from decaying vessels, structures, and dumping; some municipal trash; some discarded ship wastes. Quantity of debris affected by tides.
Northeast	Port of Philadelphia	Some man-made wood; large amounts of natural wood after severe storms; some municipal trash.
Northeast	Delaware Bay	Some floating wood in small concentrations; some marsh grass, etc.
Northeast	Baltimore Harbor	Large amounts of floating wood, mostly man-made; some municipal trash. Quantity of debris greatly affected by tides and winds.
Northeast	Washington D. C.	Moderate debris problem consisting of natural wood, found in large quantities during spring and fall.
Northeast	Chesapeake Bay	Some wood items from rivers and derelict boats, but not in appreciable quantity. Large amounts of marine growth that could be severe problem in inshore spill.
Atlantic Ocean	Offshore, entire	Very small debris problem with respect to oil spills. Quantity of debris very small relative to other areas.

TABLE 1. (Continued)

Region	Area	Debris Situation
Mid-Atlantic	Norfolk, Hampt n Roads	Large amount of wood drift. Wood is man-made in Port area, natural outside of area. Wood would be problem in oil spill.
Mid-Atlantic	Charleston, Savannah, Wilmington Ports	Light amounts of wood debris, could become moderate after severe storm. Some municipal trash.
Florida	Jacksonville	Moderate wood problem, some natural and some man-made. Great quantities of water hyacinth in area.
Florida	Miami, Port Everglades	Large quantities of water hyacinth, seaweed, turtle grass, and sargassum weed; some coconuts and palm fronds in quantity; some boating and municipal debris.
Florida	Tampa Bay	Lily pads and hyacinth in great quantity; some wood in limited quantities.
Gulf Coast	Mobile Bay	Light wood normally, can become moderate during flooding of rivers after storms; some sea grass in shallow areas of the bay.
Gulf Coast	Mississippi River	Moderate floating wood normally, increases to heavy during periods of extremely high water. During flooding large objects can come down river. Some municipal debris and floating oil drums found in small quantity.
Gulf Coast	Mississippi Delta, Louisiana Gulf	Reed grass, hyacinth, lily pads in great quantities in the inshore areas.
Gulf Coast	Port Arthur, Galveston, Corpus Christi Ports	Minimal debris problem; very little or no material normally, with some limited material after a hurricane.

TABLE 1. (Continued)

Region	Area	Debris Situation
Gulf Coast	Port of Houston	Great quantities of debris consisting of wood, domestic trash, brush and other items discarded in the bayous; situation worse after storm.
Gulf of Mexico	Open Water	No debris problem in open water; slight to no problem in discharge area of the Mississippi.
California	San Diego Harbor	Light debris problem; some wood, palm fronds and municipal trash.
California	Los Angeles, Long Beach Harbors	Normally light debris problem consisting of moderate wood, turtle reeds, ship and domestic trash. Can become moderate concentrations in some areas of the harbor after storms.
California	Southern California Offshore	Large quantities of kelp in the on-shore areas; minimal problem with other debris.
California	San Francisco Bay	Moderate to severe problem, mostly man-made and natural wood; worst when flood tides occur after storm; municipal, shipping, boating and other trash common.
California	Northern California Coastal	Light to moderate logging debris normally in open water; debris concentration on beaches heavy, can cause moderate concentration in near-shore areas when high tides occur. Moderate concentrations of kelp.
Northwest	Oregon/Washington Coastal	Same as above.
Northwest	Lower Columbia River/Portland	Normally moderate debris, mostly natural wood and logging debris; can become heavy with flooding; concentrations of wood in Portland

TABLE 1. (Continued)

Region	Area	Debris Situation
		area during flooding; some municipal trash.
Northwest	Straits of Juan de Fuca/Puget Sound	Moderate debris, mostly logs, bark chips, limbs, stumps, etc.; can be heavy after severe storms; some plastic sheets, shipping and boating debris; moderate to heavy kelp in places.
Northwest	Seattle/Tacoma	Heavy wood locally, from municipal, commercial and logging activities; some municipal trash, plastic sheets, etc.
Northwest	Bellingham/Everett Ports	Moderate to heavy wooden debris from logging and log rafting.
Pacific Ocean	Offshore, entire	Light to very light quantities of debris; would be no problem in oil spill.
Hawaii	Honolulu and Pearl Harbor	Light to moderate wood and municipal trash; situation worse with unusual winds.

(1) Increased use of containerization in cargo handling

(2) Tighter environmental controls by the Federal, state, and local governments

(3) Better cleanup of logging debris by loggers

(4) Shifts in the type of shorefront construction used in an area

(5) Improved flood control

(6) Implementation of regular municipal or port-authority cleanup operations.

In some regional descriptions, mention is made of debris possibilities in small, medium, and large spill situations. The estimated sizes of these spills are based on observations during the study of "average" spills throughout the United States. Small spills are intended to be spills approximately in the 10 to 1,000-gallon range; medium spills would be spills approximately in the 1,000 to 10,000-gallon range; and large spills would be those greater than 10,000 gallons. These arbitrary spill sizes are contrasted with the following definitions of spill sizes in coastal areas from the National Oil and Hazardous Substances Pollution Contingency Plan(1): Minor spill = less than 10,000 gallons; medium spill = 10,000 to 100,000 gallons; and a major spill = greater than 100,000 gallons.

G. PROPOSED DEEP-DRAFT HARBORS

Deep-draft harbors capable of offloading supertankers are being considered for sites which fall within the areas of interest of the study. Following is a discussion of the possible debris problems (or lack of problems) in the potential sites listed in a 1972 report to the Corps of Engineers by Robert R. Nathan Associates(2).

---

(1) Council on Environmental Quality, "National Oil and Hazardous Substances Pollution Contingency Plan" (August 1971).

(2) Robert R. Nathan Associates, "U. S. Deep Water Port Study", I.W.R. Report 72-8, Department of the Army, Corps of Engineers (August 1972).

1. New York Area Sites

Two possible offshore sites are proposed--a location at Romer Shoal and a location north of Sandy Hook, New Jersey. Both sites will have a minimal problem with debris. Some occasional pieces of wood driven out of New York Harbor may be encountered one at a time, but the frequency of occurrence will be low. It is more probable that floating garbage from offshore dumping of New York's solid wastes will be encountered. The reader is referred to the New York offshore regional description.

2. Delaware Bay Sites

Two proposed sites in Delaware Bay are off of Big Stone Beach and the Delaware Capes. Both locations will have the same minimal debris problem as in the open Atlantic. The reader is referred to the Atlantic regional description for more detail.

3. Gulf Coast Sites

The proposed Gulf Coast sites are south of the Mississippi/Alabama Coast, south of the Louisiana Coast, and offshore of Freeport, Texas. All the sites are well offshore and will have the same minimal debris problem as described in the Gulf regional description.

4. Los Angeles/Long Beach Harbor Sites

The proposed sites are located within the harbor areas. The debris situation in these harbor areas is described in the Los Angeles/Long Beach regional description.

5. San Francisco Bay Sites

The proposed sites in the Bay area run from Point Richmond along the Bay shore to Avon, located in Suisun Bay. The debris situation can be

severe in this area, with great quantities of floating wood occurring during certain parts of the year. Wood is present in some quantity at all times, and other items, such as plastic sheets and cans, are commonly found floating. Also, peat moss and other organic debris is encountered during some months. The reader is referred to the Angels Island area description of the San Francisco Bay regional description.

6. Puget Sound/Bellingham (Washington) Site

The proposed site in this area is 10 miles northwest of Bellingham. The debris situation in this area consists of moderate to heavy wood debris from logging. The reader is referred to the Bellingham Port and Puget Sound descriptions for more detailed information.

H. SUMMARY

In general, most of the man-made floating debris encountered throughout the United States is wood, while most of the natural debris in many areas is marine growth and, to a lesser extent, natural wood.

The relative quantity of debris found in a given area varies greatly from location to location, depending on population density, level and age of shorefront development, proximity to major rivers which flood and bring down large quantities of debris, severity of local storms, magnitude of tides (especially flood tides), the extent of logging activities, and the quantity of abandoned and decaying vessels and structures within an area. For a given area, the concentration of debris in a location is affected by winds, waves, currents, and geographical considerations.

In summary, floating debris is present in some areas of the United States in quantities that have been and will be major impediments to the recovery of spilled fluids. In other areas, the extent of debris effects in spill-recovery operations can vary from being a moderate impediment to not being a factor. Where debris is present in quantity, the spill-recovery efforts will be more costly and time-consuming than in areas with little or no debris concentrations.

I. CONCLUSIONS

(1) Most of the man-made debris (by weight) that is found in the areas of interest of this study is wood. This wood may be natural or cut wood, or a combination of the two, depending on location.

(2) Open-water, man-made debris concentrations are very sparse, with the exception of the Northwest United States. The open-water debris in the Northwest is mainly logs and logging debris that are driven out to sea.

(3) A major source of debris in the New York, Boston, Baltimore, Norfolk, and San Francisco port areas are the old, poorly constructed, war-time shorefront structures, which have decayed into the water. These older ports generally have the worst man-made debris quantity problem.

(4) Rivers carry far more debris during floods than other periods because of the increased water levels that occur, along with the destructive action of the storms that cause the flooding. These factors cause much more wood to be floated into and transported by rivers during flood periods.

(5) A great many derelict structures and vessels are present in several port areas. These abandoned items are generally wood and are a major source of floating debris.

(6) Debris concentrations within a region depend greatly on local currents, winds, and geographical factors. The areas where debris concentrates and the quantity in these areas are therefore very local in nature within a region.

(7) The recent awareness of the public with respect to pollution of waterways has resulted in legislation which is reducing the debris problem nationally. Containerization of cargo is also reducing the input of debris into harbors considerably due to the discontinuation of dockside unpacking of cargo.

(8) Very large quantities of marine growth are present in the areas of interest of this study. This growth could cause severe problems when cleaning up large spills.

(9) Port debris-cleanup operations currently underway do not completely remove the debris present in those areas. Enough wood remains to hamper spill-cleanup operations.

J. RECOMMENDATIONS

(1) The Coast Guard should initiate or become involved in joint debris-oriented programs with the Environmental Protection Agency, the Corps of Engineers, and the Navy. This would help to eliminate overlapping efforts by these organizations. Since there is much common interest and activity in debris-related areas, a coordinated debris effort would be in the best interests of all concerned.

(2) The use of aerial surveillance should be considered to identify and monitor local areas where specific debris concentrations exist. Trends could be established and the effects of source removal programs evaluated. Planning for pollution-response equipment regional deployment would also be facilitated by having up-to-date debris quantity information for these debris-prone areas.

CHAPTER III. DEBRIS-HANDLING EQUIPMENT AND TECHNIQUES

A. INTRODUCTION

As more and more pollution-control experience is gained, it is becoming clear that special equipment and techniques are needed to deal with waterborne debris. In many oil spills, the amount of oil-soaked, floating debris recovered in the cleanup operation has been many times greater than the amount of oil recovered.

This chapter examines the factors affecting the selection of equipment and techniques for debris handling, the state of the art and general effectiveness of the various methods of debris handling, and possible ways to improve these methods. Design considerations for new debris-handling systems are included, along with recommendations for systems that would be most effective in a given situation. Techniques and equipment from industries not normally associated with oil-spill cleanup are included in the discussion.

B. SELECTION FACTORS

The factors which govern the selection of equipment and techniques for coping with debris in an oil spill are unique in each incident, as no two spills are exactly alike. There are certain major factors, however, which should be considered. All of these factors are closely interrelated, and decisions regarding spill-recovery equipment should not be based on one or two factors alone. Further, the factors which determine procurement of equipment for a particular spill may be entirely different from those factors used by a spill-cleanup contractor or cooperative to decide what equipment to keep on hand permanently.

1. Regional and Geographical Considerations

The geography, topography, and climate of the region, as well as the commercial, industrial, and cultural characteristics of the area, affect the selection of debris-handling equipment.

Geographical features such as topography; presence of rivers, lakes, or woods; sandy or rocky beaches; firm or marshy ground; and proximity to a populated area, determine the accessibility of the spill area to mechanized equipment. They also determine whether equipment will bog down or cause extensive damage to the environment, and the kinds of transportation available to move equipment to the site. In otherwise identical spill situations, heavy mechanized equipment may be readily employed in one situation and impossible to employ in the other, depending on geographical features.

Spills occurring in heavily populated areas, such as New York, Boston, or San Francisco Harbors, are further complicated by the presence of a variety of commercial construction and materials-handling equipment which could be pressed into service for debris handling. Resort areas such as the Maine Coast offer little suitable equipment readily available. The availability of a large, cheap labor force near major population centers in the form of concerned volunteers, the National Guard, and other military reserve groups, has also been a significant factor in determining how much and what kinds of mechanized equipment to use.

Climate also influences the design and selection of debris-handling equipment. Areas that experience severe weather conditions need more highly mechanized debris-handling equipment than areas of mild weather because of the limited ability of operating crews to work in inclement weather. And areas with frequent heavy storms require sturdier, more seaworthy craft.

These are only a few examples of the types of general information about a given area which must be studied before selecting equipment designs or techniques for debris handling. The person responsible for oil and debris cleanup should be familiar with this general information as well as information on the particular physical characteristics of the area in which the spill occurs.

2. Type of Debris

The most important factor in designing or selecting equipment for debris handling is the type of debris to be handled. In the Pacific Northwest, where logging is a major industry and large floating logs are common, debris-handling equipment should include large grapples and cranes such as are used in regular logging operations. On the Maine Coast, however, where debris such as eel grass, straw, and seaweed predominates, screens, wire baskets, or conveyors could be used. Many other examples of how the type of debris affects performance requirements of debris-handling equipment appear in Section D of this chapter.

3. Spill Size and Quantity of Debris

In some past spill situations, the quantity of debris has been the same order of magnitude as the quantity of oil spilled. If large amounts of oil are involved in these situations, large quantities of debris are also involved, and the greater is the need for mechanized debris-handling equipment. These spills require large pieces of equipment with a rapid rate of recovery and extensive storage or transfer capability. Other factors affecting the specific quantity of debris, such as the normal concentration of debris in the spill area, the area covered by the spill, speed of containment, winds, and currents, are discussed in Chapter II.

4. Availability and Cost of Equipment

The factors which determine equipment availability include spill frequency and history in the general area, the location of the equipment, deployment time to the scene of the spill, method of transporting the equipment, assembly time on-scene, and availability of skilled operators.

Questions of single equipment item costs tend to be secondary, since speed is of the essence in responding to an oil spill. In general, the more quickly oil- and debris-recovery equipment can be put into service, the less costly will be the total cleanup effort. Over and above the

question of response time, the costs of procuring and operating debris-recovery equipment are determined by the size and complexity of machinery, ease of operation (requirement for skilled operators), durability and reliability, on-scene staying capability, power and/or fuel requirements, and adaptability of the equipment to other tasks.

In many areas of the country, the major oil companies have banded together to form oil-pollution-response cooperatives, such as Clean Bay, Inc., in the San Francisco Bay area and PICE Co-op, in the Long Beach/Los Angeles area. These cooperatives maintain lists of readily available equipment in their areas for use in oil spills. Much of this equipment is applicable to the problem of recovering and handling debris. In many other areas of the country, the Coast Guard Contingency Plans for Oil and Hazardous Materials and some civilian oil-spill contractors maintain lists of readily available equipment for coping with debris.

5. Spill-Cleanup Techniques

The choice of spill-cleanup technique is intimately connected to, and sometimes determined by, the choice of debris-handling technique. Ideally, these two systems should work together without interference. For example, if barriers are used to contain the oil and oily debris, the debris-handling equipment should operate effectively without breaching the barriers. Where oil slicks are formed, the debris-recovery operation should disturb the oil as little as possible to avoid emulsifying water and oil. The total effectiveness of the oil/debris cleanup effort depends on the compatibility of the debris-handling equipment with the oil-spill cleanup system.

6. Location and Characteristics of Spill Site

These factors include the geographical location of the spill site; the general type of spill site (open ocean, major port, small bay, harbor, river); currents; tidal fluctuations; water depths; accessibility of

shore-based working sites (proximity to roads, railroads, airports, shipping terminals); and water traffic conditions. These factors play roles in the selection of debris-handling equipment.

In addition, open-ocean spills require large, seaworthy waterborne equipment, whereas spills in rivers or near piers in harbors may allow debris-handling equipment to work from shore. Currents, tides, and water depths may preclude the use of waterborne equipment entirely. Remote areas may require helicopters to transport personnel and equipment.

7. Weather and Weather-Related Conditions

These factors consist of local weather conditions, such as wind, rain, temperature, and visibility, as well as weather-related conditions, such as heavy seas and flooding. Severe weather conditions complicate the oil/debris recovery effort and may curtail operations entirely. Heavy seas can capsize workboats, skimmers, and other waterborne equipment. Floods not only aggravate the debris situation, but also have been known to carry away oil and debris retention barriers, debris fences, and nets.

8. Post-Recovery Considerations

Post-recovery considerations include temporary storage, processing (if any), transport, and ultimate disposal of oil-soaked debris. In some instances, disposal of oily debris has been the cleanup coordinator's biggest problem. Burnable oil-soaked debris cannot be burned cleanly except in special open-air incinerators, and nonburnable debris requires specially prepared disposal sites (if used for landfill, for instance). The temporary storage of oily debris presents special problems because most oil-spill-response equipment has no provision for on-board storage of debris. Processing of oily debris at the recovery site, such as mulching or compacting, would help to reduce the volume required for on-board temporary storage and transport, but there are numerous problems associated with such a proposition.

9. Secondary Environmental Effects

Debris-handling equipment should be chosen to minimize damage to the environment caused by operation of the machinery. It can be argued in many oil-spill situations that the damage caused to beaches, river banks, and other shoreline areas by such heavy equipment as bulldozers, backhoes, and front-end loaders, is greater than the damage that results from the oil spill.

10. Adaptability to Marine Environment

In many recovery operations, equipment must be pressed into service which is not normally used at sea or in a marine environment. Such equipment must be able to be loaded aboard a ship or barge and operated safely and effectively at sea.

C. FUNCTIONAL REQUIREMENTS OF DEBRIS-HANDLING SYSTEMS

This subsection discusses the general functional requirements of equipment and techniques to handle debris in oil-spill-cleanup operations. The topics discussed below form a basis for evaluating existing systems and formulating design guidelines for new or modified systems.

1. On-Scene Functions

These considerations deal with how well the piece of equipment or system performs once it is in operation at the spill site.

a. Rate of Recovery

This refers to the rate at which debris can be removed from the spill site, and is usually stated in cubic yards per hour, tons per hour, or similar units. Obviously, recovery rate should be maximized for any given piece of equipment.

b. Versatility

This describes the ability of the equipment to operate efficiently in heavy concentrations of debris; the largest, smallest, and heaviest piece of debris that can be handled; and any special problems associated with certain types of debris, such as rubber tires; lumber with metal spikes or fittings; or long, stringy pieces. Equipment should be as versatile as possible.

c. Temporary Storage Capacity

This refers to the amount of debris that can be stored temporarily at the cleanup site without hindering cleanup efforts. It includes storage on board the recovery vessel itself or on auxiliary vessels, such as barges and lighters. Temporary storage capacity should be compatible with the recovery rate and expected staying power and trip time.

d. Seaworthiness

This refers to the ability of the system to perform well in severe weather and weather-related conditions, such as high winds, heavy seas, strong currents, floods, rain, snow, or poor visibility. Seaworthiness requirements depend upon the conditions in which the equipment is intended to be used.

e. Compatibility

This refers to design features of debris-handling equipment which allow effective operation in conjunction with oil skimmers, spill booms, sorbents, etc., and yet minimize effects which might hinder oil-recovery or containment operations.

2. Deployment Considerations

a. Size

The overall dimensions of a system or item of equipment are important in determining its transportability. In the case of equipment which can be disassembled for transport, both the knocked-down and the assembled dimensions are significant. Dimensional limits for highway, rail, and air transport must be considered, depending upon the intended or likely mode of transportation used.

b. Weight

Weight is also a prime factor in determining transportability and applies, as above, to the total system as well as to its component parts.

c. Complexity

System or component complexity here refers to the ease of assembly on-scene, ease of operation, and ease of deployment and recovery at the spill site. Equipment should be as simple to assemble, deploy, operate, recover, and maintain as possible.

d. Air Transportability

This includes all the special requirements for air transport including size, weight, resistance to vibration and shock, packaging, hazardous materials, and provisions for parachute delivery.

e. Maneuverability

This refers specifically to the ability of the equipment to be maneuvered (either on land or water) at the scene, including propulsion

power, speed, draft, range, and ability to operate in heavy debris concentrations. Equipment should be as maneuverable as possible.

f. Staying Time

This refers to the length of time the equipment can remain in continuous operation without interruptions for maintenance, refueling, etc. The staying time should be matched to the need for crew shift changes, trip time, and on-board storage capacity.

g. Effect on Environment

This refers primarily to land-based equipment, such as tractors, front-end loaders, and backhoes, which could cause extensive damage to sensitive areas onshore near spill sites. Such equipment should be designed for maximum footprint area and minimum weight to minimize environmental damage.

h. Trip Time

Trip time is the time required for a debris-recovery vessel to return to shore, offload debris, and return to the cleanup site. Trip time is a function of spill-site location, vessel speed and maneuverability, debris recovery rate, onboard storage capacity, and offloading rate. Obviously, a minimum trip time is desirable.

3. Logistics

The logistics of debris recovery consist of all the items of equipment, material, and services required to support the operation.

a. Auxiliary Equipment

Auxiliary equipment includes any additional equipment required to get and keep the actual debris-handling equipment on scene, including such items as launching hoists, tugboats, barges, trucks, trailers, electric power generators, auxiliary fuel tanks, etc. A systems approach to design should be employed to minimize the number of auxiliary items required.

b. Consumables

These include fuels, such as diesel oil, gasoline, and kerosene; coolants; lubricants; hydraulic fluid; crew food and water; and other items that are expended at regular time intervals. Equipment requiring toxic, unusual, or hard-to-get consumables such as bottled or liquefied gases, chemicals, etc., should not be selected.

c. Manpower

This consideration includes skilled operators, unskilled laborers, and supervisory personnel on scene, as well as coordination, communications, purchasing, maintenance, repair, and other support personnel ashore. The availability of qualified manpower for all these functions is often a severe problem in spill-recovery operations, and the need for manpower in all categories should generally be minimized.

d. Maintenance

Equipment maintenance requirements include all of the consumable items, tools, and services periodically necessary to keep the equipment in proper working order, such as certain lubricants, filters, spark plugs, gaskets, seals, chains, tires, etc. The need and expense of such items should be minimized, and the equipment should be designed for easy access to and replacement of these items.

e. Repair

Equipment repair includes the spare parts, tools, and mechanics' services required to repair damaged equipment, plus consideration of the speed with which such repairs can be effected in the field. The equipment should be simple and easily understood by normal shop maintenance personnel; components should be readily removed and replaced; materials should be easily machined and welded; and special technicians (e.g., electronic) should not be required.

D. CURRENT PRACTICES IN DEBRIS HANDLING, TEMPORARY STORAGE, TRANSPORT, AND DISPOSAL

The following section describes past and present methods for coping with waterborne debris in various situations. The information was obtained from publications and from personal and telephone interviews with people with debris-recovery experience at selected locations across the United States. Operations investigated include regular, ongoing drift- and debris-removal projects such as are operated by the Army Corps of Engineers, and methods used in special circumstances such as floods and oil spills.

1. Practices Used During Oil Spills

Equipment and techniques which have been used to handle solid debris in oil spills include a wide variety of waterborne and shore-based mechanized equipment and a great number of manual techniques. There are some common features of all oil-pollution incidents, but as a rule no two oil spills are the same. This accounts for the wide variety of methods which have been used to cope with solid debris in different spills.

In some major spills, such as the Oakland Estuary spill, the San Juan River spill, and the two Schuylkill River spills, the quantity of oil-soaked solid debris encountered was far greater than the quantity of oil spilled; and cleanup efforts were mainly problems of recovering and disposing of huge quantities of solid debris. In other spills, particularly

those in the open ocean or small spills which were quickly contained, very little debris was encountered, and the debris-handling problems were relatively minor. In certain areas of the country, such as in remote areas far from large urban or industrial centers, little mechanized debris-handling equipment is available. As a result, debris-handling techniques in these areas consist almost entirely of manual efforts to pick debris out of the spill, divert it from skimming equipment, and load it by hand into open-top barrels. In some instances no attempt is made to recover oil-soaked debris, and it is simply left in the water after the oil has been removed.

There are some general observations concerning debris-handling techniques and equipment which can be made from past experiences. First, and perhaps most important, wherever feasible it is best to contain the spill as quickly as possible with barriers. Not only will this help to minimize damage to the environment due to the spilled oil, but also it will reduce the amount of debris which can become involved with the oil and thus reduce the requirement for handling oil-soaked debris.

When the oil cannot be prevented from mixing with debris, steps should be taken to keep debris out of the oil-recovery areas, since most oil-recovery devices cannot operate effectively in water which is heavily fouled with solid debris. This may involve deploying a debris fence or barrier upwind or upstream of the skimming operation (such as on the Schuylkill), employing debris-recovery equipment at the oil-recovery site to keep that area as clear of debris as possible, or removing solid debris from the water before skimming operations are begun. For spills of lighter fuel, such as diesel fuel, it is particularly important to remove debris before attempting recovery, since these fuels are best recovered by skimming equipment which is very vulnerable to debris damage.

When large amounts of debris are encountered, it is better to get some kind of mechanized equipment to the scene as quickly as possible than to rely on manual labor. Most mechanized equipment can recover debris much more rapidly than laborers, and the equipment will cost less to operate in the long run. In addition, for severe debris situations, the equipment should be as massive as possible. Some of the rigs used for debris recovery in the San Francisco Bay tankers spill could recover 100 to 200 tons in 12 hours.

There are several important points to consider when attempting to use containment barriers in significant debris concentrations. First, oil-containment barriers should not be relied on to contain oil/debris in strong currents. Even heavily constructed log booms, such as were used in the San Juan River, will part under the heavy load of debris in a current of 3 to 4 knots.

Barriers can and should be used for diversionary purposes to guide oil/debris out of the swift current and into quiet areas of rivers and harbors where recovery equipment can be positioned. Barriers require constant tending in order to adjust for changing tidal currents, to catch and divert patches of oil/debris, to keep "bellies" from forming in the barrier line, and generally to insure that they are operating properly. They should be deployed to take advantage of natural currents, winds, local recovery sites, and other features of the recovery area, especially those areas where debris naturally accumulates. When used to contain oil/debris in quiet waters, they must be continually adjusted to concentrate the layer of oil/debris for maximum effectiveness of the debris-recovery equipment.

In almost every major spill involving debris, there has been a lack of on-board storage capacity on waterborne recovery systems. Provisions should be made either to provide adequate storage containers for oily debris on the recovery vessels, or to station debris barges near the cleanup site as was done for the Coyote and Raccoon in San Francisco. Storage containers for oil-soaked debris must be watertight and not affected by water/oil/debris mixtures.

Where waterborne or land-based equipment cannot maneuver, debris cleanup becomes a manual operation, such as along highly developed shoreline areas, under piers and docks, between pilings, in marinas, on isolated beaches, in very shallow water, and along river banks. In some situations, however, high-pressure water hoses and propeller wash from powerful boats can be used to great advantage to flush oil/debris from confined areas to where it can be recovered by mechanized equipment. In other cases, where recovery of beached oil and debris is not feasible, the oil/debris can be refloated with the incoming tide or with hoses and maneuvered to a

suitable recovery site using containment barriers, water jets, or propeller wash.

In many major spills, huge amounts of straw and other sorbents are broadcast to help minimize the effect of the oil on the environment. In many cases the beneficial effects of the straw are partially negated by allowing the oil-soaked straw to foul the beaches or to hamper oil-skimming efforts. As indicated in the Santa Barbara Channel spill, cleanup of beached oil-soaked straw and debris requires a great deal of mechanized equipment and manual labor. Open-ocean recovery of oil and oil-soaked straw and debris during the Santa Barbara Channel spill and others could have saved many man-hours of manual labor which were expended to clean up the beaches, jetties, and marinas. But a system capable of open-ocean recovery of oil/debris has not yet been fully developed. The straw-recovery rigs used in San Francisco worked well in the protected waters of the Bay, but development of a system to efficiently recover large amounts of oil/straw/debris in the open ocean would seem to be advisable.

Debris transport and disposal present another set of unique, and often major, problems. If a disposal site for oily debris is not immediately available, the temporary storage facilities of the debris-recovery rigs will become overtaxed and the oil/debris-recovery operation will grind to a halt. Likewise, if there are not enough trucks to transport debris to a disposal site, the recovery operation will be hampered. On-scene burning of oily debris would alleviate many disposal problems, but in past instances, the air pollution from burning was unacceptable. On-site burning of oil-soaked debris utilizing a mobile, forced-air burner would seem a viable alternative to open burning or landfill disposal.

As shown by the two Gulf of Mexico platform fires and the San Clemente spill, debris-handling problems in open-ocean spills under normal conditions are often minimal. In cases like these, every effort must be made to keep the oil from reaching beaches and protected water where debris tends to accumulate in order to circumvent the additional problems of recovery and disposal of oil-soaked debris.

The details of past experience with debris in 12 major oil spills, from which the observations above are drawn, are described in Appendix G. The reader is referred to that appendix for an in-depth discussion of these incidents.

2. Snag Operations and Harbor and Coastal Drift-Removal Operations

Snag operations and harbor and coastal drift-removal programs throughout the United States were researched during the study. These programs are described in detail in Appendix H. Snag operations are conducted by the Corps of Engineers to remove hazards to navigation from navigable waterways. The drift-removal programs are run by the Corps, various state authorities, port authorities, and other local agencies to remove hazards to navigation, for aesthetic purposes, and to reduce fire hazards in harbors.

Much of the equipment used in these operations (especially the drift-removal operations) has been and can be used successfully for debris removal from oil spills. The large debris-recovery vessels used by the Corps have been especially successful in debris removal from spills. In the San Francisco Bay Chevron tanker spill and the Oakland Estuary spill, the Corps' vessels, Coyote and Raccoon, played important parts in the spill recovery. Vessels used for port drift cleanup have also been used effectively for removal of drift from oil spills. The reader is referred to Appendix H for detailed descriptions of this equipment.

3. Other Debris-Recovery Operations

Regular drift removal operations are conducted on several reservoirs in the United States. These operations are described in detail in Appendix I. These drift-removal activities remove trees, parts of trees, cut logs, and other logging debris from the reservoirs to allow recreational use of the lakes and to minimize damage to hydroelectric facilities. Some of the equipment used in these activities, such as the log-rake crane attachment described in Appendix I, could be used to advantage in oil-spill operations.

E. POTENTIALLY USEFUL EQUIPMENT

This section examines new, untested pollution-response equipment designed to cope with debris, and equipment currently being used in industries unrelated to oil-pollution control. The equipment from unrelated industries was evaluated to determine its possible usefulness for debris handling, transport, temporary storage, and disposal. Many types of equipment used in the construction, materials handling, and logging industries, and other fields, show promise for spill-operation work.

1. New Developments in Pollution-Response Equipment

a. Rheinwerft

This firm in West Germany has developed a catamaran-type anti-pollution barge that is shown in Figures 2 and 3. The design is notable in that it combines debris handling and storage capability with oil-skimming and temporary storage functions. Debris is recovered by the front-end-loading rake and dumped into debris containers which, when full, can be floated and towed alongside or picked up by a crane. The craft would be well suited to small spills involving a moderate amount of debris, but its limited on-board debris storage capacity of 12 tons when fitted with three containers, would hamper its effectiveness in a major debris situation. There also appears to be no provision for off-loading the floating containers onto an auxiliary barge or onto land without floating the containers on the surface and backing down the catamaran, an operation which would require very calm water.

b. JBF DIP Skimmer/Mulcher

JBF Scientific Corporation, of Burlington, Massachusetts, is currently conducting research tests, under contract to the Civil Engineering Laboratory of the U. S. Navy, to determine the feasibility of incorporating a debris-handling system into its DIP-3001 series self-propelled oil skimmers.

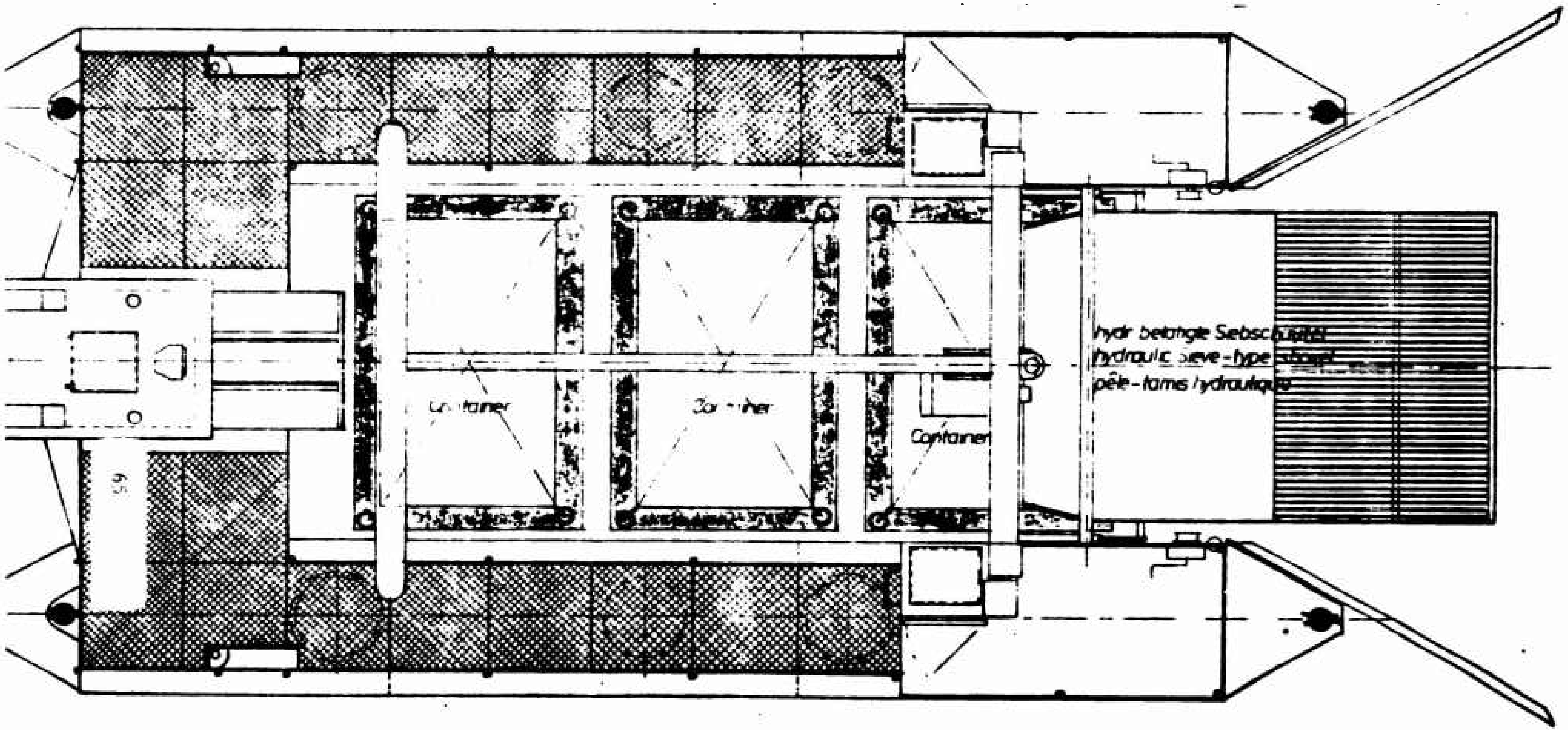


FIGURE 2. RHEINWERFT WATER MOP, PLAN VIEW[1]

(1) Courtesy, Rheinwerft GmbH & Co., Mainz-Mombach, West Germany.

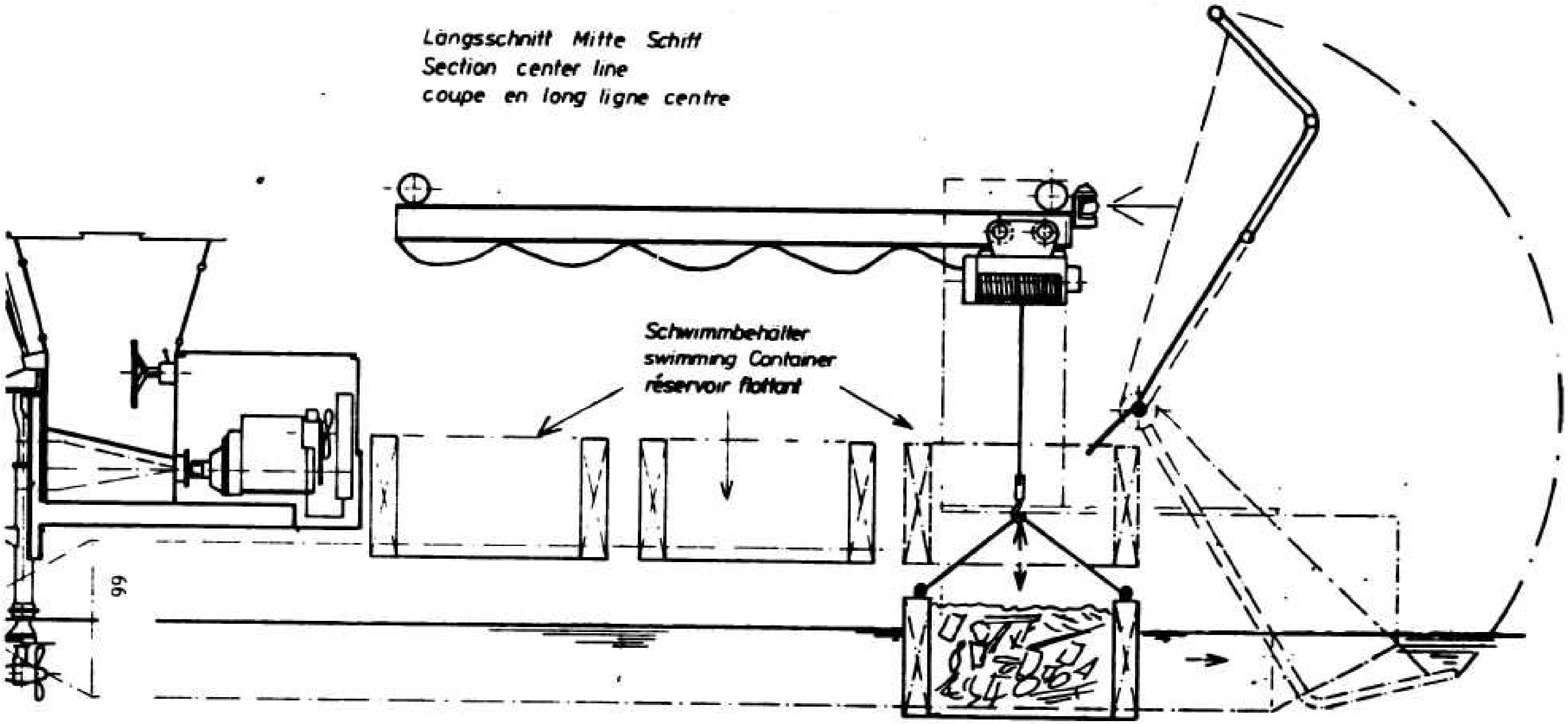


FIGURE 3. RHEINWERFT WATER MOP, CENTERLINE SECTION[1]

(1) Courtesy, Rheinwerft GmbH & Co., Mainz-Mombach, West Germany.

The added system components would consist of a mulcher or grinder such as the May-O-Rotor of Gorator, mounted in the skimmer's oil-collection well to mechanically grind or mulch pieces of solid debris into relatively small particles (1 to 1-1/2-inches in diameter) which could then be pumped along with the oil or oil/water mix into temporary storage tanks. The pumps to be used are flexible, progressing cavity pumps manufactured by the Moyno Company and can easily pump liquid/solid sludge with up to 50 percent solid particles.

c. MARCO

The MARCO Pollution Control Corporation of Seattle designs and manufactures oil-recovery systems, and two of their designs incorporate debris-handling features. The Class 3 Oil Recovery System is a 57-foot 6-inch twin-screw catamaran equipped with twin oil/debris-recovery conveyor belts mounted between the hulls. The first set of conveyor belts is of an oleophilic material which recovers oil and debris from the water. The debris is dumped onto a second, porous set of belts while the oil is squeezed off the first belt by rollers into an oil/water separator. The solid debris is carried by the second set of belts to a disposable trash container farther aft. Full specifications of the system are given in Figure 4. As seen in these drawings, a hydraulic boom crane for handling large items of debris can be mounted forward on one side of the catamaran or aft on the centerline.

MARCO's Class 2 Oil Recovery System is a 40-foot self-propelled catamaran similar to the Class 3, but with a single set of recovery belts. The Class 2 is designed primarily for operation in protected water and can be operated in water less then 3 feet deep. Twin diesels with water-jet propulsion plus optional bow thruster jets give the craft excellent maneuverability and a cruise speed of about 10 knots. High-pressure water-spray barriers can be deployed for herding oil and small categories of debris into the recovery belts. Debris from the conveyor belt can be loaded into a special buoyant trash bag, which can be stored on board or dropped over the side for later pickup. A debris-handling davit crane can be mounted aft, as shown in Figure 5, to augment the belt recovery system. The Class 2 System can be transported aboard a standard 40-foot flatbed trailer and can be airlifted. Full particulars are given in Figure 5.

PARTICULARS

LOA -- 57' 6"

BEAM -- 23' 6"

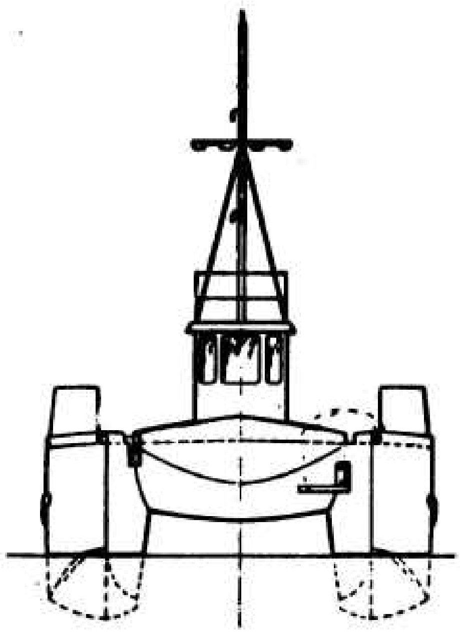
DRAFT -- 3' 10" EMPTY
6' 9" LOADED

DISP. -- 35 TONS

PROPULSION -- TWIN "CAT" 3160 DIESELS (RATED 210 HP EA.) WITH HAMILTON 1312 JETS

PUMPS -- TWIN 250 GPM GRINDING TYPE WITH SCREW FEED

OIL STORAGE -- 90 BARRELS



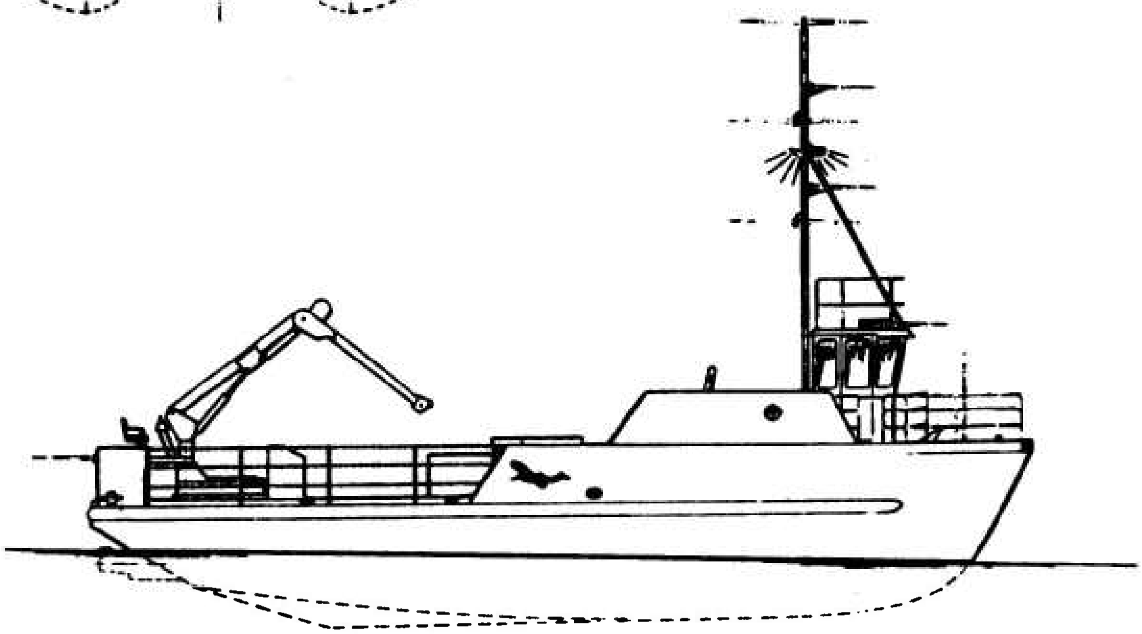
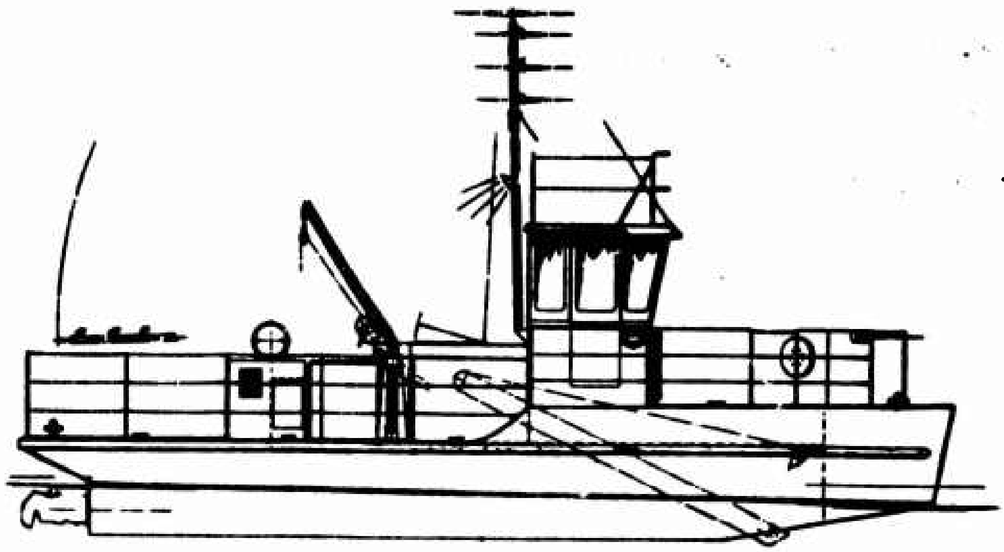


FIGURE 4. MARCO CLASS 3 OIL RECOVERY SYSTEM (1)

(1) Courtesy MARCO, Seattle, Washington.



PARTICULARS

LOA -- 39' 10"

BEAM -- 11' 10"

DRAFT -- 20" EMPTY
27" LOADED

WEIGHT -- 10 TONS

PROPULSION -- TWIN "CAT" 3160 DIESELS (RATED 210 HP EA.) WITH HAMILTON 1313 JETS

PUMPS -- TWIN 250 GPM GRINDING TYPE

OIL STORAGE -- 28 BARRELS

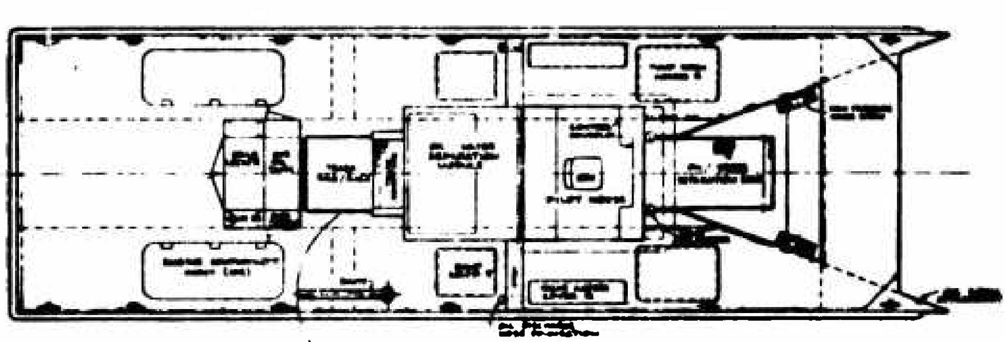


FIGURE 5. MARCO CLASS 2 OIL RECOVERY SYSTEM (1)

(1) Courtesy MARCO, Seattle, Washington.

d. Mop-Cat

Oil Recovery Systems, Incorporated, of Mineola, New York, has designed a debris-pickup accessory for its Mop-Cat water-jet-driven, catamaran-type oil-recovery vessel. As shown in Figure 6, the rectangular, two-sectional, floating debris container fits between the catamaran hulls and is capable of holding 120 cubic feet, or 10,000 pounds of debris. The manufacturer claims that the debris container is specifically designed to minimize handling of debris from water to shore, presumably by hoisting the floating container by crane directly onto a truck.

2. Potentially Useful Equipment From Areas Unrelated to Oil Spills

One of the goals of this study was to identify and evaluate equipment from areas unrelated to oil-spill-recovery operations that might have application for debris recovery, handling, temporary storage, or disposal. The detailed information concerning this equipment is given in Appendix J.

Equipment areas researched include

(1) Logging and lumbering equipment
(2) Materials handling equipment
(3) Materials processing equipment
(4) Solid waste disposal equipment
(5) Agricultural equipment
(6) Construction and demolition equipment
(7) Dredging equipment
(8) Fishing industry equipment.

Equipment from the construction and demolition industries such as cranes, backhoes, skiploaders, and dump trucks has been and will be used successfully in oil spills for handling debris. On-scene burning equipment from the solid waste disposal industry appears to have great promise for debris disposal in oil spills. Logging and lumbering equipment such as grapples and mulchers also shows promise for debris-handling activities. Some equipment used for materials handling and processing such as conveyors and shredders could be useful for debris handling. Some fishing equipment such as shrimp-trawling rigs could be adapted to debris-collection activities. Dredging equipment was not determined to be useful for debris handling.

The rectangular two-sectional floating debris recovery unit conveniently fits between the catamaran hulls and is capable of containing up to 120 cubic feet or 10,000 lbs. of debris. It is specifically designed to minimize handling of debris from water to the shore.

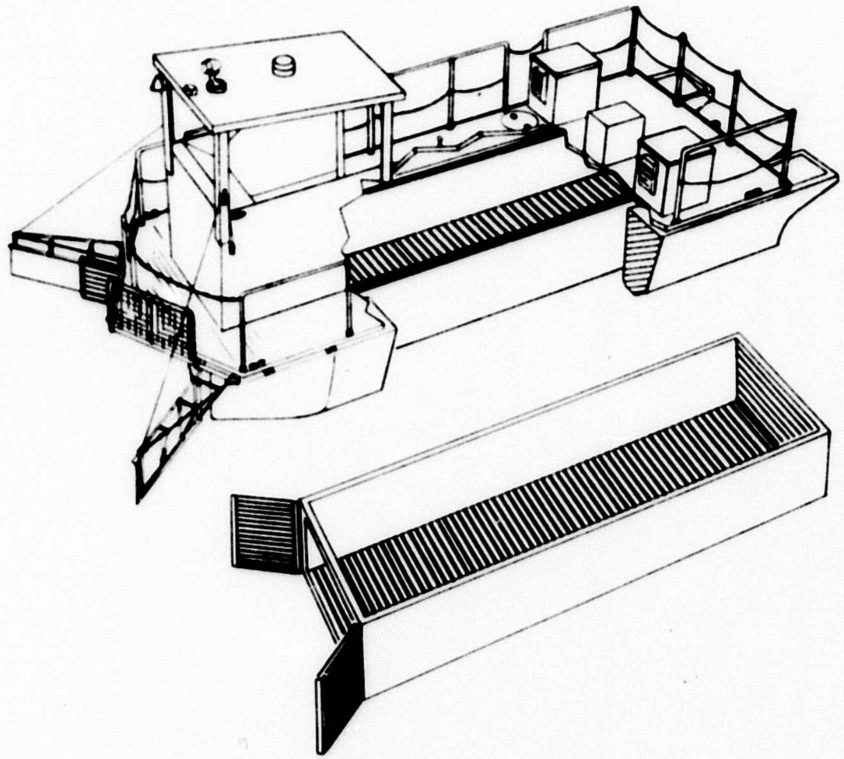


FIGURE 6. MOP-CAT DEBRIS RECOVERY UNIT(1)

(1) Courtesy, Oil Recovery Systems, Inc., Mineola, New York.

The equipment described above and in Appendix J generally needs adaptation and further development before it could be used in spills. With further development, much of the equipment evaluated could add efficiency to debris-related operations.

F. EVALUATION AND RECOMMENDATION OF DEBRIS-HANDLING METHODS

Debris-handling requirements were subdivided into eight separate and distinct functions to more meaningfully evaluate the effectiveness of equipment or techniques to cope with debris in an oil spill. These are

(1) Containment/diversion
(2) Recovery of floating debris
(3) Removal of debris from beaches or shorelines
(4) Temporary on-scene storage
(5) Processing
(6) Transfer
(7) Transport to disposal site
(8) Disposal

The containment/diversion function refers to the containment or diversion of floating, scattered debris; patches of mixed oil and debris, windrows of oil-soaked debris, etc. Containment is entrapping or encircling waterborne debris and may involve artificial or natural barriers or areas where debris tends to collect naturally. Diversion involves the use of some artificial barrier or force to direct floating debris to an area where it can be more easily contained, concentrated, and recovered.

Recovery of floating debris refers to picking debris up off the surface of the water. Removal of debris from beaches or shorelines considers picking up the oil-soaked debris from sand, gravel, or rocky beaches; from jetties and breakwaters; and from other shoreline areas.

Temporary on-scene storage is the temporary storage of oil-soaked debris at or near the site of debris-recovery operations prior to disposal. This may include storage on board oil-or debris-recovery vessels, on auxiliary vessels such as barges, or on nearby shore areas.

Processing of debris is anything which is done to the recovered or removed oil-soaked debris to alter its characteristics in order to (1) make

it easier to handle, (2) reduce on-scene storage requirements, or (3) make it easier to dispose of. Processing involves such things as grinding, mulching, compacting, cutting, or sawing large items into smaller pieces.

Transfer refers to moving the recovered debris from one vessel to another, or from one vessel to shore. It may involve moving the debris from a recovery vessel to a temporary storage vessel, from temporary storage to shore, from temporary storage to a disposal area, or similar operations.

Transport, on the other hand, refers to moving the debris relatively long distances to a (usually) remote disposal site. This may be by truck, rail, or water transportation.

The disposal function involves the various methods used or recommended for ultimate disposal of oil-soaked debris or oil/debris mixes. The most common method of disposal is landfill dumping, but such things as controlled burning, incineration, and recycling of waste materials are included.

1. Debris-Handling-Method Evaluation and Recommendation Tables

Appendixes K through R contain tables which list and evaluate the methods that could be or have been used to satisfy the eight debris-handling functions described in the previous section. Appendix K lists the containment/diversion function, Appendix L the recovery function, etc. Methods that have been used in previous spill situations are also identified.

The format used in these tables was developed to present the information in as compact a space as possible. After reviewing all the information accumulated during the program regarding the state of the art in debris handling, as well as information concerning new developments in oil-pollution-response equipment and potentially useful equipment from other industries, a list of equipment types or techniques applicable to a given debris-handling function was generated. The individual items on the list comprise the heading of the vertical columns on the tables, corresponding to the appropriate functions. The debris categories formulated in Chapter II of this report are the headings for the horizontal lines on each table. Each table is a matrix relating applicable equipment and/or techniques to debris categories for a given debris-handling function.

To more meaningfully relate applicable equipment and techniques to debris categories, the tables for containment/diversion and for recovery of floating debris are subcategoried according to situations determined by winds, waves, current conditions, and other factors. Thus, for the containment/diversion function there are four separate tables corresponding to four distinct situations; and for the recovery of floating debris there are five separate tables corresponding to five distinct situations. These distinctions are explained more fully in subsequent portions of text.

The effect of the quantity of debris encountered in an oil spill has not been evaluated directly in the formulation of these tables because it was felt that debris category and other factors involving the debris situation were the more significant factors. For example, the fact that large, general wood items such as logs, telephone poles, etc., are encountered in a given situation requires that a piece of equipment capable of recovering large wood items be used, whether there are 10 logs or 1,000.

Some functions are more sensitive to the quantity of debris involved than others. Temporary storage requirements are directly related to the quantity of debris, but they are also strongly affected by the debris categories involved. In general, it can be said that the more debris is encountered, the larger the capacity or the greater the number of storage containers will be required.

For most debris-handling functions, this principle applies: the type of equipment or technique best suited to a given function is determined primarily by the debris category and certain other factors such as debris concentration, current strength, and wave height. The quantity of debris involved generally determines how many pieces of equipment should be used.

2. Discussion of Methods of Satisfying Function Requirements

The following section discusses the methods described in Appendixes K through R for satisfying the debris-handling-function requirements.

Preceding page blank

a. Containment/Diversion

In many oil spills, recovery of spilled oil and floating debris can only be accomplished after the oil and/or debris is contained and concentrated by a barrier. This is usually accomplished by containing the oil/debris within an artificial barrier, such as an oil-containment barrier or log boom, or diverting the oil/debris into natural catch basins or calm-water areas such as coves, boat slips, locks, or sharp bends in a channel. In some cases, the same barriers used for oil containment are suitable for debris containment; but in many cases a separate debris barrier should be used to prevent damage to oil-recovery equipment and to allow separate recovery of debris and oil.

(1) Situation I. Protected water; current less than 1/2 knot. This situation was chosen because it is a very common one in harbors, ports, marinas, small bays, and other protected-water areas; and because containment is relatively easy in these conditions. Most commercially available oil containment barriers are capable of containing many categories of debris under these conditions, and some particularly sturdy oil barriers will contain virtually all categories of debris. There are several other acceptable alternatives, but note that the most highly recommended method of containment is the utilization of natural debris-collecting areas (see Appendix K).

(2) Situation II. Protected water; current up to about 2 knots. This situation is also fairly common in many harbors, rivers, ports, and protected bays. The upper limit of approximately 2 knots was chosen because very few oil-containment barriers are effective in containing oil or debris in currents this swift. Note that many other containment or diversion methods are ineffectual in currents up to 2 knots, including high-pressure water hoses, propeller wash from small boats, air-bubble barriers, and air jets. There are still several acceptable methods of containing or diverting debris in this situation, but again the utilization of natural debris-collecting areas is the most highly recommended.

(3) Situation III. Protected water; currents up to 6 knots. This situation is found in some bays, rivers, harbors, and estuaries; and it seems to represent an upper limit for most kinds of containment or diversion methods. At 6 knots, containment of debris is extremely difficult and can be accomplished only by the sturdiest cable-reinforced wire-mesh or chain-link fences or barriers. Some large log booms can be used for diversion, but they are not particularly effective for containment. Again, the preferred method is to divert debris into calmer, natural collecting areas.

(4) Situation IV. Debris concentrations in the open ocean tend to be orders of magnitude lower than in protected waters. The containment/diversion of debris becomes mainly a matter of protecting oil-recovery equipment rather than of handling debris. If significant concentrations of debris were encountered in the open ocean, the most acceptable method of containment would be to use a porous wire-mesh- or chain-link-fence-type barrier. Some oil-containment barriers are also acceptable for containing or diverting certain categories of debris.

b. Recovery of Floating Debris

This function is subdivided into separate situations depending upon whether the debris is contained and concentrated by a barrier, whether the debris is in open ocean or protected water, and whether the debris is in very shallow water. These situation factors were chosen because they along with debris category and, to some extent, quantity of debris encountered, determine which recovery methods are most suitable.

It is significant that there is no one method in Appendix L that is preferred for all debris categories for any particular situation. This means that no single type of equipment is recommended for all debris categories in a given situation. The most effective system for recovery of floating debris would consist of several types of recovery equipment such as a log grapple, a wire-mesh basket on a crane, and a debris conveyor--all mounted on one vessel.

(1) Situation I. In this situation the debris is in protected, navigable waters and is contained by an artificial or natural barrier. The debris may be near shore so that recovery equipment can be mounted on a waterborne vessel or operated from a shore, pier, or bridge. There is little or no current at the actual recovery site.

This is a common situation in many oil spills. The fact that the debris is contained means that recovery devices which can operate from a stationary platform and pick up debris over the top of a containment barrier are at an advantage compared to those devices which require forward motion of a vessel to pick up debris. Thus, crane-mounted baskets, dragline buckets, and grapples are more highly recommended than such equipment as front-end-loading baskets, nets between catamaran hulls, or baskets hung in place over the side or bow of a vessel. It is significant that there are several basic types of equipment which are considered at least acceptable for all categories in this situation and are highly recommended for many categories.

(2) Situation II. The debris is in protected, navigable water; but it is not contained by any barriers and is usually found scattered or floating in patches or windrows. The currents, winds, and wave heights are variable. In this case the equipment must either be mounted permanently on a suitable vessel or be mounted temporarily on a vessel of opportunity such as an LCM, LCU, a barge, etc.

This situation favors the type of equipment which is highly maneuverable and which collects debris as it moves through the water, such as a front-end-loading basket on the bow of a debris boat or debris nets between catamaran hulls. Other items such as grapples, clamshell buckets, dragline buckets, etc., are not as well suited to this situation, because the debris is not concentrated in one area. It is significant, however, that a debris basket mounted on an articulated hydraulic crane is highly recommended for most debris categories in this situation as well as in Situation I. Manual techniques for debris recovery in this situation are not recommended.

(3) Situation III. This is an open-ocean situation with the debris contained by artificial barriers.. As in the previous situation, the equipment can be either permanently mounted on a suitable vessel, or temporarily mounted aboard a suitable vessel such as an LCM, LCU, barge, etc. This is similar to Situation I, except that the vessels upon which the recovery equipment is mounted must be seaworthey enough to operate in moderate seas in the open ocean. This rules out the use of debris nets between catamaran hulls, because operators of this type of vessel do not consider them suitable for open-ocean operations.

For safety reasons, manual techniques are considered acceptable for certain debris categories only under extremely calm conditions. It is significant that the most highly rated types of equipment in this situation are basically the same as for Situation I.

(4) Situation IV. This is an open-ocean situation which involves scattered, uncontained debris similar to Situation II. Again, the recovery equipment may be permanently mounted on a suitable vessel or temporarily mounted on a seaworthy vessel of opportunity (LCM, LCU, barge, etc.).

As in Situation II, this situation favors equipment which is highly maneuverable and can gather debris as it moves through the water. Debris nets between catamaran hulls are again ruled out, and grapples, clamshell buckets, and conveyors are at a disadvantage because of the scattered nature of the debris. Manual recovery techniques are considered unacceptable for safety reasons and because of the scattered debris situation.

A good example of a suitable open-ocean recovery system is the Rig Engineer described in the summary of the San Francisco Bay Chevron tankers collision.

(5) Situation V. In this case the debris is found in very shallow water (1 to 2 feet), such as in the intertidal zone in bays, harbors, marshes, or perhaps along open-ocean beaches. In many parts of the country this is the area where debris concentrations are the most severe. The debris may be scattered or contained by artificial barriers.

This is a special situation where the water depth precludes the use of large vessels and barges; and, therefore, recovery equipment must be either capable of being operated in shallow water or mounted on amphibious vehicles such as surplus DUKW's or LARC's which are capable of operating on land as well as on water.

Much of the equipment which can be used successfully in deep water is at a disadvantage in this situation because it requires sufficient water depth to be able to get under the floating debris and lift it out. Clamshell buckets, grapples, and dragline buckets can be used with some success; and manual recovery techniques, although not highly recommended, are acceptable for some debris categories. In general, though, there is no highly recommended method for recovering debris from very shallow water.

In the past, most oil and oil-soaked debris which found its way into very shallow water was allowed to come up on the shore where beach cleanup techniques were employed. This method results in severe contamination of shoreline areas, and further research into the development of equipment for shallow-water recovery of oil/debris is strongly recommended.

. Beach Recovery

A comprehensive discussion of the problem of recovery of debris from beach or shoreline is beyond the scope of this report, but the general topic is included because it is usually a major part of any spill cleanup operation. A stable sand, gravel, or rocky beach is the only type of situation presented in the tables since this is the kind of situation in which heavy equipment can be used with minimal damage to the environment. There are other situations in which debris must be recovered from shorelines, but which involve either environmentally sensitive areas such as marshlands, wooded river banks and flood plains, mangrove swamps, etc., where heavy equipment should not be used; or areas such as jetties, breakwaters, and rip-rap along shore where the debris-recovery operation is necessarily a hand-picking proposition. There are also areas where heavy equipment could be used, but which are inaccessible.

For nearly all debris categories, front-end loaders seem to be best suited for recovery of debris from beaches. They are readily available throughout the country, come in a wide variety of sizes and loading capacities, can be equipped with a number of other accessories such as backhoes, trash rakes, hydraulic-boom cranes with grapples, etc., and can be fitted with special tires or tracks to minimize wheel damage to the environment. Front-end loaders are limited in their ability to handle very large logs, telephone poles, pilings, etc., but cranes with log grapples or some log loading/stacking equipment could be used for these large items. Front-end loaders work best if beached debris is first raked or gathered into piles or rows for easy pickup, and this may involve the use of modified road graders, bulldozers for particularly large pieces, or manual labor.

An excellent source of information on the use of heavy equipment for beach cleanup and restoration is the EPA report, "Evaluation of Selected Earthmoving Equipment for the Restorarion of Oil-Contaminated Beaches", by James D. Sartor and Carl Foget of URS Research Company, San Mateo, California[(1)].

Recovery of debris from shoreline areas which are easily damaged by heavy equipment has traditionally been a manual operation, although in some cases horse-drawn equipment has been used. This is an area where further research efforts should be directed. Vehicles equipped with large, low-pressure, balloon tires should be investigated as possible mounting platforms for debris-handling equipment.

d. Temporary On-Scene Storage

Current and past practices in oil spills indicate that temporary storage of recovered debris has been accomplished basically by whatever means have been available at the time, with little consideration given to ease of handling, prevention of leakage, or the need for further handling of oil-soaked debris during subsequent transfer, transport, and disposal operations.

---

(1) Sartor, James D. and Carl Foget, "Evaluation of Selected Earthmoving Equipment for the Restoration of Oil-Contaminated Beaches", URS Research Company, San Mateo, California (October 1970).

Steel 55-gallon drums have been used extensively, but they are difficult to handle even when half full of oil/debris. Plastic trash bags, metal or plastic trash cans, and wooden crates and boxes are similarly unsuitable for medium and large categories of debris and require considerable manual handling in subsequent transfer and transport operations. These items are marked acceptable for some debris categories, because they are well suited for small-spill situations and are cheap and readily available. They are not recommended for situations in which significant amounts of debris can be expected.

Temporary storage in the bottoms and on the decks of workboats, on scow barges, and on flat barges is acceptable in most situations but requires further handling of debris during transfer operations.

The most highly rated methods for storage are standard steel trash containers and dump trucks or trash trucks which can be mounted on barges or other vessels of opportunity. These containers are suitable for all categories of debris except extremely large items, and they minimize the need for additional handling of debris in subsequent transfer and transport operations. Standard trash containers can be easily off-loaded by cranes, and trucks can simply be driven off the vessel to shore. Trash containers are readily available in most urban areas in the following sizes and capacities:

Dimension, width x length x height, in feet	Capacity in cubic yards	Empty Weight, in pounds
8 x 22 x 3.4	20	6,350
8 x 22 x 4.3	25	6,600
8 x 22 x 5.1	30	6,910
8 x 22 x 6.8	40	7,740
8 x 22 x 9.0	60	10,000
8 x 25 x 14.0	100	20,000

Most trash containers and dump trucks are not watertight, so consideration must be given to the use of large plastic-sheet liners to prevent leakage of oil from the containers during storage, transfer, or transport operations.

Floating debris containers have been proposed by two designers of debris-recovery equipment(1, 2). These containers appear to have certain limitations on the size categories of debris which they can accommodate and would require very calm water to be floated. They do offer an interesting alternative to the on-board storage limitations of small craft.

e. Processing

There has been very little processing of debris in past oil-spill cleanups. In some situations, recovered items of obvious value such as drums of paint or chemicals, cases of canned goods, bales of cotton, and other salvageable items have been sorted out by hand and reclaimed for salvage or returned to their original owner. In some instances, large items of wood have been cut to smaller lengths to facilitate recovery from the beach or from storage, and occasionally oil-soaked debris has had to be mixed with straw to prevent leaching of oil from landfill disposal sites.

Processing of debris, either on scene during recovery or at a remote site, deserves further consideration and research. Large, bulky items can be mulched or ground into small chips which can then be handled and containerized more easily. Some oil-soaked items can be cleaned and reclaimed or recycled. Burnable oil-soaked debris can be pulverized into small chips and used as boiler fuel. Oil-soaked debris and recovered oil which is contaminated with solid debris can be mulched or ground into an easily pumped slurry to facilitate transfer and storage in tanks or vacuum trucks.

f. Transfer to Shore

The two best systems for off-loading debris from recovery or storage vessels involve transfer of standard trash containers by crane or simply

---

(1) Oil Recovery Systems, Incorporated, 146 Second Street, P. O. Box 167, Mineola, L. I., New York 11501, Telephone (516) 747-3457.

(2) Rheinwerft GmbH and Co., Mainz-Mombach, West Germany.

by driving off filled trash or dump trucks. Both of these methods would be very effective in handling large amounts of debris, with trucks having the additional advantage of being able to drive right off to a disposal site. No information is available from past spills to indicate that trucks mounted on barges have been used for combined on-scene storage and transfer functions.

In general, manual transfer methods are not recommended for situations involving large amounts of debris. For small spills, however, there is usually very little debris collected, and manual techniques for some categories are acceptable.

Conveyor-type systems deserve further consideration and research effort, particularly in cases where recovered debris is of a generally uniform size and consistency, or where debris can be processed to reduce large items to uniform, small chips. Conveyor systems could also be used to off-load debris containers of a uniform size, although they are more suitable for handling bulk materials.

Many spill-cleanup contractors use vacuum trucks for recovery, storage, and transport of spilled oil and oil/debris mixes in which the pieces of debris are small enough to pass through the vacuum hoses. Vacuum hoses could, therefore, be used to transfer mixed oil/debris slurries from recovery/storage vessels to vacuum trucks in cases where debris sizes are suitably small. This system would work particularly well in cases where the oil/debris mix was processed in a grinder/mulcher. Further research in this area is necessary to find optimum systems.

g. Transport

In past spills, transport of oil-soaked debris to remote disposal sites has usually involved dump trucks or trash trucks carrying standard-sized debris containers. These seem to be perfectly suitable except for extremely large items of debris, but care must be taken to seal the trucks and containers to insure against leakage of oil. Sealing can easily be accomplished by lining truck beds or containers with large sheets of plastic, although sorbents such as straw could be used to line the containers and soak up excess oil.

For excessively large items, stake trucks, flatbed trailers, or logging trucks may be required. In some cases, disposal sites may be near enough to shore that scows or flat barges can be used for transport.

Vacuum trucks can only be used in cases where small pieces of debris are mixed with recovered oil, but they have the advantage of being leakproof and readily available to most spill contractors. Vacuum trucks would be particularly suitable for transport of processed oil/debris slurries.

h. Disposal

Disposal of oil-soaked debris has often been the most difficult problem to solve in past cleanup efforts. It has involved a variety of different methods in the past, but the most common procedure seems to be dumping at landfill sites, road construction sites, or other suitable areas. There are many problems associated with disposal by dumping due to the possibility of further oil contamination of nearby areas; and, therefore, this disposal method is not desirable unless it is absolutely the only alternative.

Open burning of oil-soaked debris has been tried in the past, but it is not recommended because of the air pollution it causes. Several methods of controlled burning are currently available, however; and, while these will not meet most legal air-pollution standards, they have been shown to be capable of consuming such things as railroad ties, logging slash, tree stumps, water-soaked logs, and occasional rubber tires with little or no visible emission. Systems for controlled burning should be considered for development.

Incinerators capable of meeting air-pollution standards are recommended for nearly all debris categories, but there are very few incinerators available in some sections of the country, so their use in past spill cleanups has not been reported. Logs recovered at certain dam sites have been donated to the public for firewood, and some categories of oil-soaked debris could be disposed of in this way. There are also reports of oil-soaked wood, sand, and soil being used by farmers for soil conditioning.

Some large municipal waste disposal plants include mulcher/grinders capable of reducing solid waste to very small particles which are then used for boiler fuel in electrical power plants. Oil-soaked debris, particularly wood items, could be a possible source of boiler fuel.

G. SUMMARY

The results of the debris-handling equipment and techniques research described in this chapter indicate that, in spills where appreciable quantities of debris are present, special equipment and techniques must be provided for removal of the debris. Selection considerations for this equipment, that has been used in past spills, have mainly been based on availability of the equipment. Efficiency of the equipment has not, generally, been the prime selection factor. If other, more efficient types of equipment had been readily available and had been used for debris-handling operations in these situations, the time and cost necessary to clean up past spills could have been reduced. Available equipment for performing the various debris-handling functions that are necessary in a spill-cleanup operation have been described in this chapter, and efficient handling systems for given spill situations can be assembled from the equipment described. In the future, it is expected that equipment choices for debris handling will be based on a trade-off of efficiency, cost, and availability factors which will vary greatly from region to region. Therefore, the apparent need, as far as equipment procurement is concerned, is to optimize a given piece of equipment to meet the requirements of local spill situations in the most efficient and economical manner, rather than to develop broad new equipment types.

H. CONCLUSIONS

(1) The solution to a debris-handling problem in a spill must use a systems approach in which the situation is defined in terms of debris categories and quantities, wind and current conditions, locale, etc. Each

functional requirement must be examined and the most highly recommended method selected to optimize overall efficiency. Care must be taken to be sure that the equipment selected for one function is compatible with the basic oil-spill-recovery methods and equipment types, as well as with the equipment selected for the other debris-handling functions. Sizing of system equipment must also be taken into account to insure that storage and transfer rates are compatible with recovery rates.

(2) The complete containment of spills with booms or barriers, in areas where debris sources are present, is desirable in order to reduce the amount of debris entering the spill. The containment device acts as a barrier for incoming debris and also minimizes the mixing of debris already present in a location with the oil.

(3) Mechanized equipment, in general, has been observed to be less expensive than manual labor for handling debris. The use of equipment wherever possible to replace manual labor will have a positive effect on reducing spill-recovery costs.

(4) If the spill cannot be contained in a current by artificial barriers, diversion of the spill into calm water reduces the difficulties of handling debris in strong currents. The diversion of the spill into calm water is, therefore, desirable where possible in river and bay spills where strong currents are present.

(5) Handling equipment not currently used in spills may be useful in improving spill cleanup efficiency by replacing some tasks presently performed by manual labor.

(6) Major improvements in debris-handling efficiency in spills can be gained by making existing construction and agricultural equipment more readily available to agencies responsible for spill cleanups.

(7) Many situations exist, such as environmentally fragile sites or sites where waterborne equipment cannot maneuver, where the use of mechanical equipment for recovery is difficult or impossible. In these locations, the use of manual labor is the only acceptable alternative for recovering debris.

(8) Ultimate disposal of oil-soaked debris has been a severe problem in spills where burning has been prohibited by air-pollution regulations.

In these situations, the location of acceptable landfill sites and the transportation of the debris to these sites have been major efforts.

(9) Most debris-handling shortcomings in past spills have been due to the nonavailability of equipment rather than to the functional deficiencies of present equipment. These shortcomings have mainly occurred in spills that have occurred away from industrialized areas, where heavy equipment has not been available.

I. RECOMMENDATIONS

(1) Lists of locally available debris-handling equipment should be included in regional contingency plans to allow on-scene commanders to become aware of the local resources available for handling debris.

(2) The requirements for and local sources of debris-handling equipment should be established if detailed local debris-quantity information becomes available for areas prone to large oil spills. These requirements could be part of a larger regional-response plan for large spills.

(3) Local sites for ultimate disposal of oil-soaked debris should be pre-established in areas where debris is found in appreciable quantities. This would eliminate the problem of locating a local disposal site after a spill has taken place.

(4) The further exploration of the feasibility of on-scene processing of debris should be undertaken to facilitate storage, transfer, and disposal of debris. If this is found to be feasible, spill-recovery efficiency can be greatly improved.

(5) The use of on-scene disposal devices, such as controlled burning techniques, should be explored further. The use of on-scene disposal techniques would provide an even greater increase in spill-cleanup efficiency than the use of on-scene debris processing. If the air-pollution problem could be solved, this appears to be the most economical and efficient method for disposing of oil-soaked debris.

(6) The Coast Guard should consider joint purchase of debris-handling equipment with other organizations interested in debris recovery. This

would minimize initial equipment capital expenditure and operating costs. The Corps of Engineers, especially, has similar requirements in the debris-handling area.

CHAPTER IV. EFFECTS ON AND PROTECTION OF POLLUTION-RESPONSE EQUIPMENT FROM DEBRIS IN OIL SPILLS

A. INTRODUCTION

Debris affects every piece of pollution-response equipment in some way. This chapter describes these effects and the equipment design features and techniques that have been or are being used for protecting equipment from debris effects. The pollution-response-equipment design features and protection techniques are evaluated, and the more effective methods are recommended for use in minimizing or eliminating detrimental debris effects on this equipment.

The descriptive information contained in this chapter was obtained from in-person and telephone interveiws with these data sources listed in Appendixes A, B, and C. Most of this information came from personal observations of situations that occurred during past oil spills. Since in many cases the spills had taken place some time in the past, the quality of the observations undoubtedly varied according to the recall ability of the individual observer. The information contained in Section B of this chapter should, therefore, be considered highly subjective in nature.

B. EFFECTS OF DEBRIS ON POLLUTION-RESPONSE EQUIPMENT

The effects of debris described in this section have a commonality in that they reduce the overall spill-recovery efficiency. These decreases in efficiency generally result in lowered spill-recovery rate, use of more manpower to recover a spill, or, in extreme cases, an unsuccessful recovery operation. Normally more than one of the effects to be described occurs coincidentally in a given situation.

The descriptions of effects on pollution-response equipment are listed in the following sections under three general equipment headings--containment devices, recovery devices, and auxiliary equipment. Appendix S summarizes these observed or probable effects by debris category.

1. Containment Devices

Containment devices are used to surround and contain a spill until it is recovered. The devices currently in use are generically referred to as barriers or containment booms. Debris affects containment devices by impairing performance, thereby causing the device to be incapable of containing the spill.

In the absence of wind, wave, or towing forces, debris alone has minimal effects on containment devices. The damaging effects of debris result when the forces above are transmitted by the debris. These forces, developed in containment devices by debris contact, can be the result of hydrodynamic forces, inertia forces, or both. When a quantity of debris is contained in a sweeping operation, the forces exerted by debris on the barrier are almost entirely caused by hydrodynamic effects. The hydrodynamic forces developed are related to the relative velocity of the water and the opposed surface area, and the shape of both the barrier and the debris. In calm waters, hydrodynamic force effects are minimal.

When debris is traveling with moving water, the force imposed when it strikes the barrier is the result of deceleration of the debris. Similarly, in a sweeping operation or when towing a barrier, the forces exerted by a single large piece of debris upon contacting the barrier are the result of the acceleration of the debris.

Following are effects of debris upon containment devices. In each case, the debris interferes with the function of the containment device in some way.

a. Breaking

Breaking takes place when the developed tensile force becomes great enough to exceed the tensile strength of the barrier. The barrier can then no longer contain and control the spill. There are two general situations in which containment devices break:

(1) Large pieces of moving debris strike the device, or a moving containment device strikes a large piece of debris. These large pieces of debris exert enough inertial force to break the barrier. The types of debris capable of exerting such forces are logs, partially full oil drums, pieces of wharf, large timbers, and other objects which have large inertias.

(2) A large quantity of debris is retained in moving water, causing hydrodynamic forces sufficient to break the barrier. With sufficient quantity and high currents, any category of debris is potentially capable of exerting forces large enough to break barriers.

b. Puncturing, Tearing, and Chafing

A punctured or torn barrier is not completely separated, as in the case of a broken barrier. With a punctured or torn barrier, the contained spill may pass through the opening, and hence is not completely under control.

Debris with pointed ends, sharp corners and edges, or debris with metal fasteners, nails, straps, or belts usually causes most punctures and tears. The categories of debris causing this kind of damage are mainly wooden items and rigid sheets.

Chafing is a longer-term failure caused by the rubbing or abrasion of a piece of debris against a barrier. Chafing of a barrier may also occur because of deployment around a piling or some other fixed object, with the resulting damage not directly caused by debris.

The occurrence of a puncture or tear does not necessarily render a barrier ineffective. An opening where the spill fluid is in contact with the barrier causes a more severe problem than an opening above or below the fluid-contact area. In some calm-water spills no leakage occurs because punctures are below the waterline. However, in a rougher sea, intermittent leaking of fluid through openings above and below the normal waterline may result from the fluctuating water level. The rate of fluid flow through a leak depends on many factors such as the size and shape of the opening, the location of the opening with respect to the slick, the slick thickness, the

wind and current direction, the amount of debris present, and the type of debris contained by the barrier.

c. Sinking

Sinking of a containment device occurs when positive buoyancy is lost or overwhelmed, and the device either sinks below the spill fluid or loses enough freeboard so that the fluid passes over it. Depending upon the design, buoyancy can be lost in a number of ways. Regardless of the design, sinking can result from puncturing or tearing and, in some designs, from breaking. In this latter case, a compound loss of containment control occurs due to both breaking and sinking.

A puncture or tear can cause varying degrees of buoyancy loss in an air-chamber system. If just one chamber is punctured or torn, the barrier may not sink, depending on the design. Large, compartmentalized, foam-pellet buoyancy chambers lose buoyancy as a result of pellet loss. Some barriers use a redundant technique employing small watertight packages containing foam pellets within the watertight barrier, thus minimizing the danger of sinking due to punctures or tears. Nevertheless, sinking of these barriers has occurred even though the pellets must pass through two fabric layers before being lost.

Contained foam logs are also used in some designs. These barriers usually must suffer a large rupture for the log to escape and cause buoyancy loss. For externally attached buoyancy, floats must be removed or torn from the barrier by snagging for buoyancy to be lost. When barriers break, an entire compartment can be opened, with the possible loss of buoyancy from that compartment due to loss of air, pellets, bags of pellets, or foam logs.

Types of debris that cause puncturing, tearing, and breaking were described in the sections above, entitled Breaking; and Puncturing, Tearing, and Chafing. The debris categories that cause snagging will be described later.

d. Forced Submergence

Forced submergence of a barrier occurs when the sheer weight of debris forces the barrier under water. Forced submergence does not cause any physical damage, but when the barrier is submerged, the contained spill and debris may pass over it. Two modes of barrier submergence have been noted. In one case large pieces of wood, such as logs, roll or turn over; and branches or other protrusions lay across the barrier and force it under. The second mode of forced submergence occurs when masses of material such as straw build up in front of a barrier. If the buildup exceeds the height of the barrier, it can spill over and submerge it due to the weight of the oil-soaked material. This effect is compounded by the hydrodynamic forces moving the debris toward the barrier.

e. Lifting Up

Lifting up of containment devices occurs when they are raised so that the lower edge of the skirt clears the water surface. Lifting up can occur when large pieces of wood or logs roll over and swing a protrusion or branch under the barrier, lifting it clear of the water. It can also occur when debris is driven under the barrier by wind, current, or towing motion. The barrier is then lifted by the buoyancy of the trapped debris.

f. Upsetting of Trim

The trim of a containment device is upset when it is forced out of the attitude intended by the designer. This problem tends to occur with curtain-type barriers that have flotation devices along their sides and is not as common where large, cylindrical flotation chambers are located above the skirt. Upsetting due to debris is caused by hydrodynamic or gravity forces. The barrier may not have sufficient freeboard or draft to contain the spill when its orientation is altered. Most categories of debris have the potential to cause upsetting, especially when encountered in large quantities.

g. Snagging

Snagging occurs when debris becomes entangled or fouled. This commonly happend around mooring and anchoring lines or in the exposed flotation systems of some designs. Barriers designed with gentle curves and smooth surfaces are not as susceptible to snagging as are other designs. Irregularly shaped pieces of wood, flexible sheets, and filamentous pieces of debris are the types which most often cause snagging. Snagged debris can cause upsetting, chafing, puncturing, and tearing. Large pieces of snagged debris such as logs can cause barriers to break. In many cases these forces would not have developed if the snagging had not occurred.

Another significant problem caused by snagging is that the fouled debris must be removed before the last traces of the spill can be recovered and the barrier retrieved.

h. Deployment Hindrance

In many situations, debris has been a hindrance during the deployment of containment devices. Larger pieces of debris can prevent the assumption of proper trim, and the upsetting debris must be removed. Maneuvering barriers through such debris is also a difficult problem. The debris interferes with boats and lines which are used to deploy the barriers into the desired configuration.

2. Recovery Equipment

Recovery equipment, as defined in this study, is equipment used to pick up fluids spilled on water. During the course of spill-recovery operations, recovery equipment may be used alone or with containment devices. At times, recovery equipment and containment devices are integrated and operated as a single unit, using a sweeping technique to recover the spill. This section describes the effects of debris on recovery equipment. The discussion is divided into two sections. The first section covers fluid-transfer systems, which form a part of all pollution-response devices. The second section discusses the skimming equipment which removes the oil spill from the water.

a. Fluid-Transfer Systems

The transfer system of a pollution-response device is used to move the recovered fluid from the recovery device to a temporary storage container. Two basic types are commonly used--vacuum systems and positive-pressure pump systems.

(1) Vacuum Systems. In general, debris causes relatively little equipment downtime in vacuum systems used for fluid transfer. That which does occur consists mainly of blocking or clogging of hoses, straight piping, and elbow fittings in the plumbing system. Clogging can result only from ingestion of debris which fits through the initial system opening. Most of the clogging results from long, slender, rigid types of debris such as branches and sticks, which lodge in bends and elbows of the plumbing. Debris larger than the system opening cannot enter the system. Debris with an overall envelope size smaller than the hose diameter will generally pass through the plumbing system and into the temporary storage container. Plumbing systems used on current skimmer designs commonly have 2-, 3-, or 4-inch-diameter piping. The larger, 4-inch-diameter hose systems do not experience the frequency of clogging encountered in the 2-inch systems.

Debris accumulates in the tanks that receive the recovered oil and debris from vacuum systems. Much of this debris leaves the tank during normal unloading operations; however, some can remain trapped. Debris which remains after unloading must be removed manually, and a sufficiently large man-way or hand-hole access cover is required to permit cleaning.

(2) Positive-Pressure Pump Systems. Debris can affect positive-pressure pump systems just as it does the vacuum systems. Again, it is frequently the long, slender, rigid types of debris that lodge inside the plumbing.

Generally, debris affects all rotating-type pumps in some manner. The following effects have been observed: Excessive wear on pump components; jamming, stalling, or prevention of shaft rotation; and deformation or breakage of parts. Flexible sheet-type debris, such as plastic garbage bags, wrap around the rotating components and cause stalling.

Reduction in pumping rate due to wear, deformation, or breakage contributes to reduced pumping efficiency. When a pump stops rotating, stalling or seizing of rotating components can damage those components which drive the pump.

Diaphragm-type pumps are utilized in many recovery systems, with a noticeable degree of success. Most debris which enters the system will be passed through these pumps. However, long, slender debris, such as twigs, kelp, shoelaces, fishing line, rope, and popsicle sticks, can become lodged in the check-valve seats, thus impairing or stopping the pumping action. Plastic bags, paper, and condoms are examples of other items that frequently interfere with the operation of diaphragm pumps.

b. Skimming Systems

Skimming systems vary in size from small, hand-portable units to large, manned boat systems. For the purposes of this section, sorbent-broadcast-and-recovery devices are categorized as skimming systems. The following discussion covers the various effects debris has upon skimming systems. Four general categories of recovery devices are discussed: Weirs; rotating drums, discs, and belts; dynamic inclined planes; and sorbent-broadcast-and-recovery systems.

(1) Weirs. Weir-type skimming devices include many designs--small portable, linear, and circular floating weirs; larger weirs on floating platforms or vessels; and fixed-installation weirs. Debris causes the following various effects on weirs:

(a) Bridging. Bridging is caused by the accumulation of debris around the intake portion of the recovery device. This accumulation often builds up to the point where the surface fluid cannot flow through the debris to the skimmer and is partially or completely "bridged" underneath or around the skimmer inlet.

The trim adjustment for weirs is usually set with the lip of the weir at or near the water surface. Debris which is not drawn into the weir

by hydrodynamic forces usually has a draft which is too great for it to clear the lip of the weir. This debris will be held against the weir by the relative current between the water and skimmer. As the collection of deeper-draft debris increases, the accumulation not only stops the oil spill from reaching the skimmer reservoir, but also collects the smaller debris that would normally pass over the weir, thus further compounding the impediment of fluid flow.

(b) Upsetting of Trim. Floating weirs are subject to changes in trim which result in reducing the effectiveness of recovery. Debris snagging on smaller weirs easily changes the trim. When trim changes, the weir depth also changes, causing thinner or thicker cuts of the surface layer. Also, the lip of the weir may be skewed so that it is no longer parallel to the water surface. Medium and larger types of debris cause trim changes.

(c) Displacement Change. Displacement changes occur when the total weight of the skimmer changes, usually due to changing load conditions aboard the skimmer. These load changes may result from temporary storage of recovered spill fluid, from accumulated on-board stowage of recovered debris, or from the removal of these loads. Trim change may also occur with displacement changes. In any event, skimmers are usually very sensitive to displacement and trim adjustments, and changes to these adjustments due to the intentional or unintentional accumulation or removal of debris will affect the function of most weir skimmers.

(d) Physical Damage. The larger sizes of rigid types of debris can cause physical damage when colliding with or impacting weir-type skimmers. Bending and breaking of the weir can be a result of this impact. Debris impact can also damage the flotation system for various weir devices.

(e) Reservoir Clogging. The reservoir from which the recovered spill fluid is pumped is located behind or downstream of the weir. Debris which has crossed the weir collects at the intake to the transfer system. The accumulation of debris can cause bridging which reduces or stops

withdrawal of fluid from the reservoir. Any type of debris which crosses the weir can collect and impair transfer-system flow.

(f) Sinking and Forced Submergence. Sinking of a recovery device can result from impact with large rigid types of debris. Small skimmers have been forcefully submerged by encounters with large logs or other large debris. Large debris can also remove flotation components, thus imparting a loss of buoyancy to some skimmers. Hollow flotation systems are subject to puncturing by large debris or by sharp metal objects in wooden debris. Resulting flooding of these spaces can bring about sinking of the recovery device.

(2) Rotating Drum, Disc, and Belt Devices. There are many types of rotating-drum, disc, and belt-type recovery devices, ranging in size from large, self-propelled systems to small, portable designs. Following are descriptions of several kinds of effects which debris has on these types of equipment:

(a) Bridging. Bridging of debris has the same effect on rotating-drum, disc, and belt recovery devices as it has on weir types. The reader is referred to the weir device section for detailed discussion of these effects. Each of these three types of devices has an entry way through which the oil and debris pass to reach the recovery mechanism. Some devices have a single, large opening and may or may not have a screen across the opening for keeping out the larger sizes of debris. Other devices have several small openings. In either case, debris which is too large to pass through the entry will collect in front of the opening. Soon this debris collection grows and prevents the spill fluid and normally acceptable debris from reaching the skimmer. All sizes of debris can cause the bridging effect.

(b) Mechanical Jamming. Debris can become snagged on drum and disc mechanisms and jam or lodge between the drum or disc and the support structure in such a manner that the drum or disc is prevented from rotating.

Medium and large pieces of wood, rigid shapes, rigid sheets, and cans and bottles frequently cause this problem.

Rotating-belt systems have been stopped by debris entangling with the belt and guide pulley and forcing the belt off the pulley.

(c) Disc Wiper Damage. Rotating-disc wipers can be damaged or their efficiency impaired by debris. When recovering very viscous fluids, small debris can stick to the disc and collide with the wipers. If the wiper does not have the proper contact and angular relationship with the disc, the recovery efficiency is reduced. The impact of debris with the wipers can upset the relationship.

(d) Impact and Catastrophic Failure. The primary mechanical elements of drum-, disc-, and belt-type skimmers can be completely destroyed by impact with large sizes of debris, rendering them totally inoperable.

(e) Tearing of Sorbent Materials. Drum- and belt-type skimmers which utilize sorbent materials are subject to tearing damage. As these units rotate, they snag on debris that is too large or too heavy to be picked up by the sorbent material. The debris remains in the water and tears the sorbent material before becoming disengaged. In some cases the debris may only puncture the sorbent locally, impairing performance relative to the extent of the damage.

(f) Sorbent-Belt Clogging. Incidents of porous, sorbent-belt-type skimmers becoming clogged with wood chips and fibers were reported. The particles snag in the sorbent material, causing two effects: (1) The oil is prevented from reaching the sorbent material and (2) as the sorbent material passes through the squeezing roller, the debris prevents the sorbent from being properly compressed. Either effect reduces or stops all recovery.

(3) Inclined Plane. Following is a list of effects which debris has on dynamic-inclined-plane skimmers:

(a) Bridging. This effect, previously described in the weir section, also occurs with dynamic-inclined-plane skimmers. The entrance becomes blocked with the pieces of debris, which accumulate and impede fluid flow to the skimming device.

(b) Clogging of the Reservoir. The fluid-collection reservoir downstream of the belt collects debris, which can be anything which is reached and brought down by the belt. Some skimmers of this type have a grating across the bottom opening of the reservoir that collects debris. This collection grate has, in some cases, caused oil to pass completely under the skimmer without entering the reservoir. Small- and medium-sized pieces of debris can cause this problem.

(4) Sorbent Material. Sorbent materials used for oil-spill recovery are available in many configurations including log or boom shapes, sheets, and granular forms. Up to the time of this writing, sorbent material usage is generally a manual process both during deployment and during recovery. Following are ways in which debris affects sorbent materials with respect to oil absorption and sorbent recovery:

(a) Dispersement. Debris can prevent some sorbent materials, when dispersed on a spill, from coming into contact with the spilled fluid, which is necessary for sorbent material to be effective. This problem is especially severe with sheet forms of sorbents. Sorbent logs are difficult to disperse in an area with concentrations of debris.

(b) Recovery. Medium and large sizes of solid types of debris have become entangled or snagged on sorbent logs and sheets in several reported spills. With debris snagged in the sorbent, it becomes more difficult to recover. However, small sizes of debris generally present no problem, for they are recovered right along with the sorbent, or they fall off when the sorbent is picked up.

Granular sorbent materials are usually recovered manually with debris scoops, and small debris is lifted out right with the sorbent. The

problem is that large quantities of debris may be handled in recovering the sorbent. Medium and large debris requires even more effort to move and handle during sorbent recovery.

3. Auxiliary Equipment

During spill-recovery operations, auxiliary equipment is utilized to support the containment and recovery devices previously described. This equipment can be affected by debris during recovery operations. Boats and temporary storage containers will be discussed in the following section, as they are the two types of equipment most commonly used in recovery operations.

a. Boats

Boats of many sizes and descriptions are employed for spill-recovery operations. Typical craft range from small rowboats to boats 100 feet in length or larger.

(1) Hull Damage. Hull damage is usually puncturing or denting by large debris near or below the waterline. Hull puncturing damage usually eliminates the boat from further recovery operations until repairs are made. The smaller boats of wood and fiberglass hull construction are more susceptible to this type of damage than metal-hulled boats.

(2) Impaired Navigation and Maneuverability. Medium and large sizes of debris impair navigation and may prevent a boat from proceeding in a desired direction or to a desired location. Larger debris categories are largely responsible for interference with boat maneuverability. Turning, backing down, or proceeding ahead may be prevented due to the danger of contact with debris. Maneuvering and navigating about these pieces of debris can hinder the manner in which containment and recovery equipment is utilized.

(3) Breaking of Propellers. In general, medium and large pieces of debris can break propeller blades or bend the blades to such an extent

they are no longer effective. If big chunks of debris get under a boat near the propeller, damaged propellers and bent propeller shafts can result. This damage can happen to the propulsion system of any sized craft.

(4) Fouling of Propellers and Water Intakes. Flexible sheets or filamentous pieces of debris such as plastic bags or ropes can become wrapped around propellers and propeller shafts. This can cause a significant loss of thrust, shearing of drive pins, or shaft seizing.

Water intakes can become partly or completely blocked by debris. Many types of medium and small debris can bridge across the opening or be drawn into the intake pipe. This reduces or stops water flow into the opening, and may lead to overheated or damaged engines or other equipment requiring cooling.

(5) Stability. Impact with medium and large debris can change the trim or even capsize small boats. Also, debris loaded into small boats can reduce the freeboard or the overall stability. In addition, small boats frequently do not have enough righting moment to allow for handling the heavier pieces of debris over the side without taking water over the gunwale.

(6) Impairment of Personnel Safety. Debris can create situations that constitute risks to personnel, and these can be serious if the personnel are not prepared for them. Oil-covered debris is slippery, which makes for poor footing. Sudden boat impacts with debris can cause personnel to lose balance and fall into the water or into machinery or other objects. Swamping, capsizing, hull punctures, or sinking can place the crew in swift or cold water, among debris or toxic materials, or into the path of other vessels.

b. Temporary Storage Containers

Temporary storage tanks are used as auxiliary equipment in many situations. Debris can affect these tanks, impairing their usage. These tanks are either soft- or hard-shell types.

(1) Reduction of Capacity. The purpose of the tanks is to store the recovered fluid. However, since recovery devices retrieve debris along with the spilled fluid, debris is also temporarily stored in the tanks. The volume of debris in the tank reduces the total capacity for fluids. This reduction in storage capability due to storage of debris has been appreciable in some spill situations.

(2) Clogging. Debris can clog the inlet and outlet openings of the tanks, slowing or stopping the flow of fluid. Usually, a significant amount of time and effort is required to remove the blockage.

(3) Puncturing and Tearing. Hard-shelled tanks are not as subject to punctures and tears as are soft-shelled tanks. Debris which enters a soft-shelled tank has been known to cause damage both when the tank contains fluid and when it is being packaged for storage with this debris still inside. Frequently, these soft-shelled tanks are deployed, filled, and maneuvered about while in the water, during which time they are subject to damage either by internal or external debris.

C. CURRENT DESIGN FEATURES AND TECHNIQUES FOR PROTECTION OF POLLUTION-RESPONSE EQUIPMENT

Many available pieces of pollution-response equipment incorporate design features for resisting the effects of debris. Spill-recovery organizations also utilize techniques which help reduce the adverse effects of debris upon recovery equipment. Present design practices and techniques for protecting equipment from debris are summarized in Appendix T. The following section gives descriptions of selected features or techniques from that appendix, with examples of their use. These descriptions are divided into three sections covering containment devices, recovery equipment, and auxiliary equipment. Within each section, design features and protection techniques are discussed separately.

1. Containment Devices

a. Design Features

Some containment devices have evolved to a configuration designed to enable them to better cope with debris. The following design considerations of these devices were observed during the study:

(1) Breaking Strength. Some barrier designs contain a wire-rope or synthetic-rope tension member to provide longitudinal strength to withstand applied current and towing forces. In general, barriers designed in this way have higher tensile strengths than those without tension members.

Decisions regarding the use of and sizing of tension members are based on longitudinal strength and flexibility considerations. In most cases the trade-off is made relative to whether the barrier is to be used for quick-response situations in sheltered water or in open water, or for fixed installations in areas prone to oil spills.

Barriers for quick-response situations in sheltered waters are designed to be flexible for quick deployment and ease of storage. Their relative strength, therefore, is low. Barriers designed for open-water situations are generally made more substantial to enable them to withstand high currents, severe wave action, and towing forces encountered in open-water spills. Their relative strength is high. Barriers intended for fixed installations are generally the most rigid and, in some cases, are as strong or stronger than the open-water designs.

In barriers without tension members, the strength/flexibility trade-off is generally made by varying material thickness. Thicker materials provide higher strength but also make the barrier stiffer. Stiffer barriers are harder to store and deploy and may not follow the water profile faithfully when short-period swells are present. The more flexible barriers have failed when encountering large accumulations of debris. These failures generally have occurred in the fabric at the connections or, in less frequent situations, in the connections themselves.

Some barrier designs also use relatively elastic materials or flexible connections to allow the barrier to stretch when encountering large pieces of debris. This stretching is intended to reduce the magnitude of tensile forces developed when decelerating or accelerating large debris.

(2) Resistance to Puncturing, Tearing, and Chafing. Commercial barrier designers have made some attempts to provide optimum tear, puncturing, and chafing resistance. Materials of high relative tear strength and puncture resistance, such as coated or reinforced fabrics, are used in some flexible barrier designs. However, these materials also cause the barrier to be relatively stiff and can compromise the performance of the barrier in spill situations. In rigid barrier designs, tearing, puncturing, and chafing tend to be less problematical. Rigid barrier designs cope with this problem by using thicker skirt sections. However, rigid barriers with thick skirt sections are also very heavy and, therefore, less portable.

Barriers designed for military applications also consider puncturing, tearing, and chafing problems. Military Specification B-28617(YD) contains standard tests to be performed on materials for barriers purchased for the Navy. The Specification for Mechanical Oil Barrier Systems, published by the Ocean Engineering Division of the United States Coast Guard on September 11, 1973, contains tests to be performed on barriers specified by the Coast Guard. In both cases the material tests are intended to guarantee a minimum resistance to punctures, tears, and abrasion.

(3) Stability. As has already been mentioned, debris can upset or submerge barriers. Some designs attempt to minimize this effect by providing maximum positive buoyancy and/or righting moment.

(a) Righting Moment. Righting moment is the force by which a barrier reacts to an external force acting upon it, such as that exerted by debris. When disturbed, the righting-moment force tends to return the barrier to its normal attitude. Most currently available barriers are designed with the center of gravity below the center of buoyancy. The designs with no tension member and with optimum righting-moment capability have a large

distance between the center of buoyancy and the center of gravity. Also, some barriers with relatively deep draft have a lesser tendency to be upset because it is more difficult for debris to get under the skirt.

(b) Reserve Buoyancy. Forced submergence results from vertical debris forces acting on a barrier. Current designs try to reduce this effect by incorporating the most possible reserve buoyancy, which is the capacity of an object to provide increased buoyancy as it is further submerged. Some barriers are presently designed with sufficient reserve-buoyancy capability to withstand forces from large-sized debris without submerging. For barriers in the same height class, cylindrical-float, attached-skirt designs generally offer larger reserve buoyancy than fence- and curtain-type barriers.

(c) Snagging. As previously discussed, debris can snag or foul on barriers. This tendency is minimized by avoiding protrusions and irregular shapes along the barrier containment surface. In some designs, such as fence-type barriers with attached floats, snagging of debris is a problem. Connectors also frequently offer places for debris to snag, as do grommet holes, loops, seams, bolts, and other fastener protrusions.

b. Protection Techniques

Experience gained in spill-cleanup activities has resulted in the development of many containment-device protection techniques. Techniques that were observed during the study are discussed below.

(1) Permanent Repair. Barriers damaged by puncturing, tearing, and breaking are commonly repaired for further use. Some barriers are repaired on the deck of a boat, but the majority of permanent repair work is done on shore. Holed barriers are commonly repaired by patching with adhesive, heat sealing, or applying sewn or bolted patches, depending on the material from which the barrier is fabricated and its construction. The simplest and least time-consuming method is to patch with adhesive. The other methods

generally take longer. Barrier breakage is frequently repaired by use of a connector splint or by replacing an entire section. The best method depends on local considerations.

(2) Temporary Repair. Temporary repairs of damaged barriers are effected in the water so that the spill-containment function is not interrupted or can be restored as quickly as possible.

A common practice is to replace an entire section of damaged barrier with a new section. Where possible, a damaged barrier section will be removed and the undamaged barrier reconnected. However, this procedure reduces the length of the barrier, which has caused problems in some spills. These techniques are more effectively accomplished with quick-disconnect barrier fittings which are available in some designs.

Another procedure, used for repair of punctures or tears, is to secure a new section of barrier in front of and behind the damaged section. This technique may not make a leak-proof seal, but it will reduce the leakage.

Another quick-fix technique is to slacken the barrier and tie it to itself on either side of the damaged area, resulting in a loop on one side. A variation of this technique is to fold or accordion the barrier and to secure the end of each fold to another section. Some barriers are designed to be used in this manner; and clamps, which can be placed over the barrier to facilitate this technique, are available. Moreover, some parted barriers can be repaired by overlapping and securing in this manner.

(3) Use of Double Barriers. The use of a double barrier is a technique by which two oil-containment-type barriers are deployed parallel to each other some distance apart. The purpose of the first barrier is to retain debris only. The second barrier contains the spill. In some situations damage to the first barrier may result and is accepted provided the debris is contained. If the debris barrier does not allow the spill fluid to pass, the barrier is periodically lifted just enough to allow the desired amount of fluid to flow under.

(4) Protective Barriers. Protective barriers are sometimes employed to keep debris away from the primary spill-containment barrier. The protective barriers are not impermeable as are the oil-containment barriers. Many designs and types of materials have been used in various situations. Log-boom barriers have been utilized, and this approach has been very successful in stopping logs and other large debris from contacting the primary containment barrier. Snow fence, chain-link fence, expanded metal, chicken wire, and other porous sheet materials have also been utilized. Usually, floats are attached to these materials, and ballast is added to achieve a vertical orientation for the barrier. Frequently, a tension member is used to provide the needed tensile strength.

One manufacturer contacted during the study is about to market a protective barrier. The design is very similar to the cylindrical-float, attached-skirt spill-retention barrier; but an open-mesh material is employed in place of the solid skirt. The mesh is intended to retain debris but allow the spill to pass through. Another manufacturer markets a mesh-net-type debris barrier with flotation, ballast, and tension members attached. It is intended to be deployed a short distance in front of the spill-recovery device to catch debris before it reaches the skimmer.

(5) Diversionary Deployment. Spills and debris are commonly deflected sideways by deploying barriers in a diversionary pattern. This technique is practical only in moving-water situations such as in streams, rivers, and tidal-current areas. For setting up a diversion, the barrier is deployed diagonally to the current and not at right angles as in containment use. This arrangement tends to reduce the magnitude of the forces exerted on the barrier by the debris, and debris does not build up along the barrier. Diversion barriers have been used to push both the oil and debris out of the fast current into calm-water areas where recovery work takes place.

(6) Manual Tending. Manual tending is an important technique used frequently for barrier protection. The purpose of manual tending is to prevent debris from contacting or damaging the barrier. This is accomplished in several ways--removing debris from behind the barrier; directing the

larger, potentially more damaging sizes of debris around the ends of the barrier; towing away and mooring large debris elsewhere; pushing damaging-type debris under the barrier; and lifting the barrier to allow debris to pass under. In many areas tending must be a continuous effort any time containment barriers are in the water.

(7) Utilization of Debris-Handling Equipment. Another approach used to protect the containment devices from debris damage is to remove the debris from the water. Some locations in the United States already have regular debris-recovery operations, and specialized debris-handling equipment has been developed for these operations. The types of equipment and techniques are described in Chapter III. Utilization of this debris-handling equipment in conjunction with pollution-response equipment has reduced the amount of damage caused by debris.

(8) Abrasion-Resistant Cover. One manufacturer makes an abrasion-resistant cover to prevent debris damage to the cylindrical flotation section of their barrier. The cover is used where a barrier is permanently moored and is in contact with dolphins, pilings, and other pier facilities. While this cover is available, its use was not reported in an actual debris-laden spill situation.

(9) Attached Protective Barrier. Protective barriers fabricated from chain-link fence with floats attached for buoyancy have been attached to the primary containment device in some situations. They are usually deployed using rigid poles between the two barriers. The debris barrier is held in front of and at a distance from the primary barrier, collecting the debris and allowing the oil spill to pass to the containment device.

(10) Water Jets. In some spills, water jets have been used to direct debris away from barriers. These jets were from water hoses and fire hoses located dockside or on board ship. Directing debris away from a barrier with water jets is not always effective, especially with large, nearly submerged pieces of debris in a strong water-current situation. Also,

the position and orientation of the imposed current with respect to its effect on the overall recovery operation has been a factor in controlling debris with water jets.

(11) Propeller Wash. Attempts are frequently made to use propeller wash from boats to direct or divert debris in a desired direction. Non-secured boats intermittently directing their propeller wash have provided limited debris-movement control in some spill situations, while in other instances the boats have been secured by mooring, anchoring, running aground, or pushing against a dock. As with the use of water jets, the location and orientation of the imposed current must be compatible with the equipment and the total recovery operation.

(12) Permanent Debris Barriers. In areas where frequent spills are encountered, fences have been installed to exclude debris from the area. In some cases, the barrier also protects permanently installed pollution-response equipment. The fence cannot be left totally unattended, and a regular inspection and maintenance program is usually required to make the barrier effective.

(13) Debris as a Protective Barrier. Accumulated debris sometimes functions as a protective barrier for a boom. This debris forms a zone where impact forces from large debris can be absorbed before contacting the barrier. For this to be effective, the smaller sizes of debris must build up first. This buildup of protective debris is controlled to avoid other debris-effect problems that large quantities of debris can cause. In some instances, sorbent materials also form protective barriers.

2. Recovery Equipment

a. Transfer Systems

(1) Design Features. Some of the transfer-system design features currently employed follow. No protection techniques as such for transfer systems were observed during the study.

(a) Filters. In one skimmer design a filter is installed in the plumbing system of the recovery device. The filter is located upstream of pumps and valves so that debris will not lodge, jam, or damage these components. Filter-mesh is sized small enough to catch those sizes of debris which can cause problems with the downstream machinery.

(b) Large-Diameter Hoses and Piping. Large-diameter hoses and piping are used to minimize the frequency with which debris clogs in transfer systems. Vacuum systems with 3- and 4-inch-diameter hoses are found, and 2-inch-diameter hose systems are common. The larger-diameter piping systems usually have larger-radius bend fittings, which also permit passage of debris without clogging.

(c) Quick-Disconnect Fittings. Quick-disconnect fittings on hoses and pumps are used to reduce downtime due to clogging. Clogged hoses can be easily and quickly replaced and then cleaned at a more convenient time. Quick-disconnect fittings also permit replacement, repair, or removal of clogged or damaged pumps, strainers, valves, and other system components.

(d) Pump Selection. Pumps designed for severe service or pumping of solids in suspension are used on most skimmers. Diaphragm pumps and open-impeller, centrifugal pumps are the most common types.

(e) Back-Flushing. The capability to reverse flow is incorporated in some transfer systems to correct clogging problems with a minimum of downtime. However, back-flushing usually expels some of the contained fluid back into the water.

b. Skimming Systems

(1) Design Features.

(a) Trash Screens. Trash screens are used to keep debris away from many types of recovery devices. The screen is usually located in such

a way that it stops debris but allows the spill fluid to pass into the skimmer. Saucer-shaped skimmers with circular intakes use circular screens of a diameter larger than the saucer. Skimmers with reduced entrance areas, such as many of the weir, rotating-drum, and belt types, use straight sections of screen mounted on the inlet of the device.

Trash screens are constructed of materials with various opening sizes depending upon the type of debris they are intended to exclude. The opening is usually sized to keep out debris which adversely affects the skimmer. Mesh size of 1/2 inch square is common.

One skimmer design uses two screens--an outside screen of 1/4-inch mesh and an inside one of 1/2-inch mesh. If more viscous oils are encountered and choke the outside, smaller-mesh screen, it is removed; and the larger-mesh screen is used alone.

Recovery-equipment operators frequently fabricate their own trash screens to fulfill their special needs. Debris screens fabricated on scene depend on the materials that are readily available. Expanded metal, chicken wire, hardware cloth, chain-link fence, snow fence, fish net, etc., have been used. Metal flat bar, pipe, and rod stock have been used for support structures.

Some skimmers have been equipped by the operators with special screens to avoid debris damage during transit. These guards are removed for recovery operations.

(b) Shielding of Mechanical Moving Parts. On several skimming systems portions of the linear and rotating moving components are shielded to prevent debris from jamming, wrapping around, or otherwise interfering with the operation of the equipment. Drive-trains are also shielded in many designs.

(c) Porous Debris Belt. A porous debris belt is another method used to minimize debris effects on some belt skimmers. The debris belt removes debris which has dropped off the oleophilic belt that precedes the debris belt. With this recovery technique, not only is the recovered spill fluid collected, but also the oil-soaked debris is recovered by the same process.

(d) Machinery Removed From Debris. In one oleophilic-belt-type system, the belt-driving and wringing portions of the system are isolated such that the belt and a tail pulley are the only items directly contacting the spill. Debris must become entangled and transported by the belt before it can encounter the wringer. This physical separation acts to reduce the frequency and severity of malfunctions due to debris.

(e) Cranes Mounted on Skimmers. Cranes, jib booms, and davits are installed on some larger, manned recovery devices to remove some of the larger debris that interferes with oil-recovery operations. The debris is usually temporarily stored on board the recovery vessel for later disposal.

(2) Protection Techniques.

(a) Manual Handling. Debris around a recovery device is commonly controlled by manual labor. When debris gathers, it is moved away or removed manually to minimize adverse effects on the skimmer. In many situations, continuous manual handling and tending of debris is necessary. Three variations of manual handling have been frequently used for coping with debris, as follows:

Intake Tending. Manual handling of debris at intakes is common practice with all types of skimming systems. The handling of the larger pieces of debris is important because they cause severe damage to equipment. Manually pushing, pulling, and guiding is the usual practice, using boat hooks, pike poles, debris nets, lines, etc. Larger debris is usually moored off, maneuvered around, or pushed under the containment barriers; or it is mechanically removed from the water. Smaller debris frequently bridges across the intakes and trash screens of skimmers. The accumulation is usually scooped out of the water with pitchforks, dip nets, etc., to restore flow into the skimmer intake.

When small skimmers are used, the debris is usually handled manually from the shore or a nearby dock. On larger skimmers, personnel are usually stationed at the bow or at the intake to handle the debris.

Skimmer Collection-Reservoir Tending. Another location where manual handling of debris is necessary is in the collection reservoirs of weir and dynamic-inclined-plane skimmers. In both designs, the debris is manually removed with dip nets or hand skimmers.

Tending With a Small Boat. In some cases, men in small boats are used for the manual handling of debris near skimmer intakes, especially around wharfs. The boats are moored or propelled with oars or outboard motors, depending upon the conditions. Dip nets or scoops are used for debris handling.

(b) Protective Barriers. As has been previously discussed, protective barriers are used to keep debris from reaching skimming systems, either in front of or across the intakes of the skimmers. The barriers filter out the debris and allow the oil to pass on to the skimmer. Snow fence, chain-link fence, expanded metal, and other porous sheet materials are used. One manufacturer offers a porous-type protective barrier to collect debris before it reaches the skimmer.

(c) Water Jets. As has been noted before, jets from water and fire hoses are used to direct, remove, or prevent the entry of debris to skimmer intakes.

(d) Propeller Wash. Propeller wash from boat propulsion systems is used to produce currents to move debris away from skimmers. Usually the boat is held in one position such that the resulting current maneuvers the debris in the desired direction. This technique is limited in its application since the forces exerted by the water also affect the spill fluid.

3. Auxiliary Equipment

The following are features of auxiliary equipment which improve their compatibility with debris-laden oil-spill-recovery operations.

a. Boats

Some boats which operate in and around debris situations are equipped with heavy-duty propellers that can sustain contact with debris without damage. Others are fitted with guards to keep debris from coming into contact with the propellers. These guards are usually rigid baskets which are attached to the hull and entirely surround the propeller and shaft. Other workboats equipped with jet drives experience only minimal problems with debris.

b. Temporary Storage Containers

Storage containers for recovered oil and debris are constructed of strong materials to resist debris damage. Tanks incorporate man-ways or sides that open to permit cleaning.

D. EVALUATION OF CURRENT DESIGN FEATURES AND PROCEDURES

This section contains evaluations of the design features and protection techniques discussed in the previous section. Factors observed during the study and engineering judgment were used to evaluate the advantages and disadvantages of each item.

1. Containment Devices

a. Design Features

(1) Barriers Designed for Breaking Strength. No failures of tension-member barriers were reported during the study. The use of a tension member is the preferred way to achieve high breaking strength, considering the desired flexibility range. Tension-member designs are also easier to handle than other barrier designs with similar strength. Tension-member barriers have the disadvantage of some design complexity. Where flexibility of the barrier is the primary consideration, barriers without tension members have some advantage.

(2) Material Selection for Resistance to Puncturing, Tearing, and Chafing. Punctures and tears of present barriers are more common than breaking failures. Most current barrier designs cannot stop large pieces of debris without sustaining tearing or puncturing damage. Curtain-type barriers appear to resist this type of failure better than tubular or inflatable types.

(3) Righting Moment. Barriers with no tension member and with the largest distance between the center of gravity and the center of flotation have the highest righting moment capability. Separate tension-member barriers have the least tendency to be upset by applied debris force.

(4) Reserve Buoyancy. Sinking is a common problem with present barriers in heavy debris situations, especially light barriers with small flotation units.

(5) Snag Resistance. Barriers with protruding flotation units, external lines, and bridles on the containment face, cause frequent problems with debris. Smooth-surfaced barriers are better but can still create difficulties around connections and with tending lines.

b. Protection Techniques

(1) Permanent Repair. Current practice for permanent barrier repair are adequate for the problems encountered. Most barriers can be restored to a condition which matches the original capability.

(2) Temporary Repairs. Current temporary repair practices are also adequate. Most of the temporary repair practices have evolved through field experience and are generally efficient methods for altering the problems encountered.

(3) Use of Double Barriers. This technique is effective with respect to overall spill-cleanup activities. However, the barriers used to contain debris usually sustain appreciable damage when used in this manner.

(4) Protective Barriers. Most improvised barriers work marginally well, failing on occasion by breaking, sinking, or local holing. Some improvised designs work exceptionally well, never having failed in service. Considerable time can be consumed in improvising the designs, ordering and amassing the parts, and assembling the barrier. Improvised designs are also relatively difficult to deploy and retrieve. No experience information is available on commercial protective barriers.

(5) Diversionary Deployment. This is an effective technique, especially when used on rivers or streams.

(6) Manual Tending Techniques. Manual tending is an effective technique for protecting barriers in all spill situations. Personnel can perform a variety of tasks and are usually readily available. However, the use of laborers to perform tasks that could be done by machine is more expensive in most circumstances.

(7) Utilization of Debris-Handling Equipment. Debris-handling equipment gives effective protection in light or moderate debris situations. In heavy debris, handling equipment usually cannot pick up all the debris before the retention barrier is encountered.

(8) Abrasion-Resistant Covers. Information sufficient to evaluate the performance of abrasion-resistant covers was not available at the time of this study.

(9) Attached Protective Barriers. Attaching a protective barrier is an effective technique against small- and medium-sized debris in low currents. In high currents, or when heavy debris is encountered, protective barriers are not effective in keeping debris away from the containment barrier.

(10) Water Jets. The effectiveness of this concept is limited, even for small- and medium-sized debris in low currents. Water jets can be used only in local areas. Water jets are ineffective in high currents or for handling heavy debris.

(11) Propeller Wash. The usefulness of this technique is limited due to difficulties with station keeping in currents, near moorings, and in shallow-water operations.

(12) Permanent Debris Fence. This concept is effective, but it can be used only in shallow-water areas where the fences do not cause a hazard to navigation.

(13) Debris as a Protective Barrier. This is an effective technique only when small debris is encountered first, or when large pieces are removed from the initial incoming debris. If large pieces are not removed from the debris before it encounteres the barrier, the protective action of the small debris is ineffective.

2. Recovery Equipment

a. Transfer Systems

(1) Design Features.

(a) Filters. Filters that are functioning properly must eventually be cleaned or replaced. This function might be better served by the use of inlet screens and back-flushing, which would avoid the downtime associated with cleaning filters.

(b) Large-Diameter Piping. Use of large-diameter piping is an effective method of reducing system clogging due to debris. A 4-inch-nominal-diameter system is much more effective than a 2-inch-diameter system, especially when operating in situations where large amounts of small debris are present.

(c) Use of Quick-Disconnect Fittings. Quick-disconnect fittings are very effective in reducing downtime due to debris clogging. Many spill-cleanup contractors modify equipment not originally designed with quick-disconnects to permit faster cleaning or replacement in the field.

(d) Pump Selection. Pumps designed specifically for pumping fluids contaminated with solids minimize debris effects on many skimmers. These pumps are much more effective in spills with debris than are designs that have been selected solely to provide optimum transfer efficiency.

(e) Back-Flushing. The capability to back-flush permits cleaning of clogged systems without disassembly. A disadvantage in some designs is the discharge of a quantity of the recovered fluid when back-flushing.

b. Skimming Systems

(1) Design Features.

(a) Trash Screens. Trash screens are effective in keeping medium and large debris from reaching skimmers. Disadvantages include the need for more or less constant manual tending to prevent bridging or, with some small screens, clogging during recovery of viscous fluids.

(b) Shielding of Mechanical Moving Parts. Shielding reduces jamming of components on many skimmer designs. The technique also improves the safety of some designs.

(c) Porous Debris Belts. Porous debris belts permit rapid handling of debris picked up with the spill. However, handling systems of this type require considerable deck space and space for temporary debris storage. They are also expensive.

(d) Remote Machinery. The concept of isolating the machinery from the debris eliminates many debris-related problems such as clogging, physical damage, etc. The disadvantage is that mobility is greatly reduced.

(e) Cranes on Skimmers. The use of cranes on skimmers allows recovery of large pieces of debris by the skimmer. This is an advantage when a skimmer is working a spill alone or when skimmers are used for general debris-recovery operations not associated with a spill. Disadvantages of cranes are that they are initially expensive to install; their use slows down skimming operations; most skimmers have limited on-board storage space; and an operator is required.

(2) Protection Techniques.

(a) Manual Handling of Debris. This technique has the great advantage of being versatile as to the type, quantity, and location of debris

that can be handled. The disadvantages are high cost relative to the use of machines, difficulty in protecting against large debris in strong currents, limited endurance of a single crew, and possible safety problems.

(b) Use of Protective Barriers. See the discussion of this technique above, in the Containment-Device section.

(c) Use of Water Jets. This technique also has been evaluated in the Containment-Device section above.

(d) Use of Propeller Wash. The reader is again referred to the Containment-Device section.

3. Auxiliary Equipment

a. Design Features

(1) Boats. Heavy-duty propellers greatly reduce damage and associated downtime, although such propellers can be less efficient. Propeller guards also effectively reduce damage caused by large debris. Guards, however, can be subject to fouling by small debris, plastic sheets, and other debris items. Jet drive minimizes debris damage but reduces maneuverability somewhat.

(2) Temporary Storage Containers. No data are available to evaluate debris effects on temporary storage-vessel designs.

E. RECOMMENDED DESIGN FEATURES AND PROTECTION TECHNIQUES FOR PROTECTION OF POLLUTION-RESPONSE DEVICES

Table 2, which follows, lists recommended design features and techniques for protecting pollution-response equipment from debris. The recommendations are listed by effect and effect subcategory. Where no recommendation for protection or minimization of effect can be made, none is entered for that category.

TABLE 2

RECOMMENDED DESIGN FEATURE/PROTECTION TECHNIQUE

Effect	Effect Sub-Category	Recommended Design Feature/ Protection Technique
Containment Device Breaking	Impact of Single Large Debris Pieces	Tension member Proper deployment Debris handling
	Forces from Large Quantity of Debris	Continuous debris handling Tension member
Containment Device Puncturing Breaking and Chaffing		Reinforced boom material Debris handling
Containment Device Upsetting		Tension or flotation member placed to resist overturning moments Debris handling
Containment Device Forced Submergence		Reserve buoyancy to support medium sized debris Debris handling
Sinking of Containment Device		Redundant and compartmentized reserve flotation Puncture resistant materials Debris handling
Lifting Up of Containment Device	Due to Rolling Over of Log	Design with sufficient draft
	Due to Wedging of Debris	Manual tending
Snagging	Snagging of Lines and Connection	Enclose all lines, connections, etc. with cover Eliminate projections, put on other side of barrier
	Snagging of Flotation	Put floats on one side, away from debris
Containment Device Permanent Repair		Use proven local field methods Follow manufacturer's recommendations
Containment Device Temporary Repairs		Use proven field methods Follow manufacturer's recommendations

TABLE 2. (Continued)

Effect	Effect Sub-Category	Recommended Design Feature/ Protection Technique
Deployment Hindrance		Debris handling Deployment devices
Transfer Systems Clogging	General Debris	Inlet screen or strainer Backflushing Pump selection Oversized plumbing
	Filamentous Pieces	Trash grinder Cleanout access
Jamming or Seizing of Pumps	General Debris	Inlet screens Proper pump selection Oversized plumbing Cleanout access
	Plastic Sheets	Trash grinders Cleanout access Oversized plumbing
Blocking of Intake Opening		Manual tending Backflushing
Bridging of Recovery Device	Medium and Large Debris	Trash screens Manual tending
	Small Debris	Manual tending Trash screens
Reservoir Clogging of Recovery Device		Intake trash screens Manual tending Trash grinders
Physical Damage Due to Debris Impact		Fenders Propeller shrouds Protective frames Heavy-duty construction
Upsetting of Trim		Debris handling Adjustable trim and ballast Adjustable weirs
Displacement Changes		Debris handling Adjustable ballast

TABLE 2. (Continued)

Effect	Effect Sub-Category	Recommended Design Feature/ Protection Technique
Drum and Disc Wiper Damage		Trash screens Manual tending Wiper shields
Sorbent Belt Clogging		Trash screen
Debris Wiping Oil off of Drums or Disc		Debris tending Trash screens
Dispersment of Sorbents		Debris handling Debris fence
Propeller Damage		Propeller shrouds Jet drives Heavy-duty propellers
Engine Inlet Fouling		Inlet strainer Backflushing
Personnel Safety		Correct application of equipment Careful navigation and seamanship Life jackets Safety helmets Shoes and gloves

F. SUMMARY

Debris has reduced the efficiency of recovery equipment in many spill situations. This has been especially true in spills where a great quantity of debris has been present or in spills where high currents and debris are involved. Some of the debris effects hamper spill-recovery operations without damaging recovery equipment. Other debris effects cause physical damage to the equipment. Design features and protection techniques have evolved in attempts to eliminate or minimize the effects of debris on spill-recovery equipment and operations. Many of these design features have been successful in performing their desired functions. Protection techniques have also been successful, except that many require the use of relatively costly manual labor. Some of the design features and protection techniques that are used in local areas of the United States would be useful in other local areas for increasing the spill-recovery efficiency of operations where debris is present.

G. CONCLUSIONS

(1) Present barrier designs are marginally adequate or inadequate for containment of debris in high tidal or river currents. The forces developed will fail many barriers or upset, sink, or submerge others, destroying their oil-containment capability.

(2) In many past circumstances, containment devices have been used to contain large amounts of debris in relatively strong currents. Very little knowledge concerning the forces developed in the containment devices in these situations exists.

(3) All commercially available containment devices are designed primarily to contain oil. No currently available barriers have been specifically designed to contain debris.

(4) Currently available recovery-equipment designs have more design features for minimizing or eliminating debris effects than do containment devices.

(5) No currently available recovery devices can recover oil and debris effectively in large quantities of heavily concentrated debris. The devices' skimming performance or their inability to handle the large quantity of debris restricts their performance in these situations.

(6) More widespread application of presently known design features and protection techniques could greatly improve spill-recovery efficiency where debris is present.

(7) Many of the debris problems observed with recovery equipment occur due to the use of the equipment for applications other than those for which it was intended. This is especially true for the use of light barriers in heavy debris situations and high currents.

(8) Vacuum-type transfer systems appear to cause the least trouble of all systems observed where debris damage and clogging are concerned. Their incorporation into skimmers used in moderate and severe debris situations could improve spill-response efficiency.

H. RECOMMENDATIONS

(1) The typical forces developed in containment systems when debris and currents are present should be investigated to allow comprehensive containment-system design. Containment systems could then be rated for use in particular types of debris situations.

(2) The determination of typical forces developed when large debris impacts skimmers should be determined to allow skimmers to be designed so as to be capable of withstanding these impacts. Skimmers could also be rated for use in various debris situations.

(3) The development of design guidelines to improve resistance of pollution-response equipment to debris effects is necessary before a useful specification for equipment to be used with debris can be generated. This would allow procurement of debris-compatible equipment in areas where debris is a problem.

(4) A standard debris-barrier design to be used on scene for debris containment should be developed to eliminate some of the containment

failures that currently take place in spills where debris is present. This barrier design could be either purchased beforehand or fabricated on site by the spill-cleanup personnel.

(5) The determination of the mechanical behavior of debris contained behind a barrier in a current is necessary. This would allow better containment barriers for debris to be developed. Optimal designs for containing both debris and oil could also be developed with this knowledge.

(6) Factors affecting transfer-system performance in spills with debris should be evaluated in depth. These factors would include viscosities of fluids to be pumped, pumping-head requirements, velocities developed in the system, the amount of oil/water mixing that takes place, and the tolerance of the particular system to debris. Including debris effects in the evaluation of these other considerations would allow the selection of optimum systems for the situation rather than just the optimum system for debris tolerance.

(7) When designing or modifying systems, attempts should be made to use the largest practical nominal piping with large-radius bends. The use of large-diameter piping system is a feature of most transfer systems that have minimal debris problems.

(8) Large, easily opened clean-out openings should be designed into storage containers to eliminate some of the difficulties that are encountered with inlet clogging and tank clean-out.

(9) Inlet screens designed for use on transfer-system inlets should have a surface area much larger than the pipe cross-sectional area. This would minimize inlet blocking and clogging problems caused by small debris. The use of spherical screen reinforced by a frame is suggested.

(10) Spares for key components of skimmers and barriers should be readily available for replacement of damaged equipment at the spill site. This would minimize the effect of equipment downtime due to debris damage on the overall spill-recovery operation.

(11) Filtering elements capable of stopping filamentous debris such as fishing line, rope, and kelp should be developed for use with diaphragm-pump-type skimmers and transfer systems. These devices should also be capable of stopping sticks. The use of these devices would eliminate clogging of check valves.

(12) A field book for on-scene commanders which would give information on how to build debris fences, useful hand tools, considerations in deploying barriers, and debris-handling techniques for use with skimmers and barriers should be developed. The book would foster the rapid construction and deployment of useful improvised equipment during a spill situation.

(13) The use of trash or garbage grinders to reduce debris to more readily pumpable or handleable forms should be investigated. (Apparently the U. S. Navy is pursuing such a program and has issued development contracts and a recent RFP on this subject.)

APPENDIX A

INDIVIDUALS CONTACTED IN PERSON

Appendix A contains the names and addresses of individuals who were interviewed in person during the study.

APPENDIX A

TABLE A. INDIVIDUALS CONTACTED IN PERSON

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
Coastal Services, Inc. Boston, MA	Benjamin J. Santacroce Russ Delano, Jr. Jim O'Brien	Boston, New England Coastal - Skimmers and booms
Boston Harbor Cleanup Boat	Arthur Fournier	Boston
Environmental Protection Agency Regional Headquarters Needham Heights, MA	John Conlon	New England Coastal
Army Corps of Engineers Waltham, MA	Mr. Fistel Ray Boyd	New England Coastal
JBF Scientific Corporation Burlington, MA	Ralph Bianchi	New England - Skimmers
U. S. Coast Guard Captain of Port Portland, ME	ENS Dan Riley Capt. Donald McCann	Portland, ME - Debris-handling equipment
Bureau of Waterways Department of Transportation State of Maine Portland, ME	A. Edward Langlois	Portland, ME; Maine Coastal
Seacoast Ocean Services Portland, ME	Bob Madsen Dave Wasgatt	Portland, ME; Maine Coastal - Skimmers and booms

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
Clean Water, Inc. Toms River, NJ	Paul Preus Jack Gallagher	Philadelphia, New York - Debris handling, booms
Delaware River Port Authority World Trade Division Camden, NJ	James R. Kelly William Bennington	Philadelphia Area, Delaware Bay - Debris handling
Pennsylvania Marine Police Navigation Commission Philadelphia, PA	CDR Lee Tilton	Philadelphia Area
U. S. Coast Guard Captain of Port Philadelphia, PA	CDR Mullen LTJG Steve Connelly (MEP)	Philadelphia Area
Environmental Protection Agency Regional Headquarters Philadelphia, PA	Bob Kaiser	Philadelphia - Debris handling
Army Corps of Engineers Philadelphia, PA	Nick Barbieri Walt Starret	Philadelphia
Maryland Department of Natural Resources, Waterways Improvement Annapolis, MD	Warren Shelly	Chesapeake Bay
Army Corps of Engineers Baltimore, MD	Mr. Epstein	Baltimore Harbor - Debris handling

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
Ocean Systems International, Inc. Reston, VA	Henry McKenna	- Booms and skimmers
Army Corps of Engineers New York, NY	John Zammitt Al Dorfmann Mr. Fisher	New York - Debris handling
U. S. Coast Guard Captain of Port Governor's Island, New York, NY	LTJG Steve Hughes LCDR Harbison	New York - Booms and skimmers
New York City Planning Division New York, NY	Carl Sobremisana	New York
Seward, Inc. Falls Church, VA	Louis S. Brown	- Booms
Industrial Marine Services, Inc. Norfolk, VA	James H. Parker Roy A. Kershaw	Norfolk, Lower Chesapeake Bay, Baltimore - Booms and skimmers, debris handling
Army Corps of Engineers Hampton Roads, VA	Charles Brickner	Norfolk
Environmental Protection Agency Atlanta, GA	Al Smith Jack Stonebraker Ray Wilkerson George Moein	Southeast Coastal - Booms and skimmers

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
Army Corps of Engineers Atlanta, GA	A. W. Mohr James H. Bradley	Southeast Coastal - Debris handling
U. S. Coast Guard Jacksonville, FL	LCDR S. J. Cavallaro	Jacksonville
Clean River, Inc. Jacksonville, FL	Warren Bateman	Jacksonville - Booms and skimmers
Army Corps of Engineers Savannah, GA	Steven Osvald Bill Clarkson	Southeast Coastal
U. S. Coast Guard Savannah, GA	LTJG Richard Harbert Chief Lewis	Savannah
Savannah River Oil Spill Control Committee Colonial Oil Industries, Inc. Savannah, GA	James T. Walker	Savannah - Booms and skimmers
Danmark, Inc. Miami, FL	Harold S. Daniels	Miami, Port Everglades - Debris handling, booms and skimmers
Belcher Oil Co. Miami, FL	Floyd Syrcle Gene Redfern	Miami, Port Everglades - Debris handling, booms and skimmers
U. S. Coast Guard Captain of Port Houston, TX	ENS Connor Lt. Lawrence	Houston - Debris handling, booms

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
U. S. Coast Guard Captain of Port Galveston, TX	Lt. Kein Lt. Reichersamer	Galveston
U. S. Coast Guard Freeport, TX	Various enlisted personnel	Gulf Coast, Freeport
Port of Houston Fire Protection and Traffic Control Houston, TX	Louis Brown	Houston - Debris handling
Port of Port Arthur Operations Office Port Arthur, TX	Mr. Blunstein Mr. Goldstein	Port Arthur
U. S. Coast Guard Captain of Port Sabine Pass, LA	Lt. Corpuz, Pollution Prevention Officer	Gulf Coast, Sabine Lake
U. S. Coast Guard Strike Force Bay Saint Louis, MI	LCDR Park and staff	Gulf Coast, Mississippi, Tampa - Booms, debris handling
U. S. Coast Guard Captain of Port New Orleans, LA	ENS Walker, Pollution Control Officer	Mississippi - Debris handling
Alabama State Division of Docks Mobile, AL	Jerry Tew Operations Office	Mobile Bay

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
Clean Gulf Associates New Orleans, LA	Claude Golay	Gulf Coast - Booms and skimmers
Oil Mop, Inc. Belle Chasse, LA	Dusty Rhodes	Gulf Coast, Mississippi - Booms and skimmers
MARCO Seattle, WA	William Lerch Robert Allen	Seattle - Skimmers
U. S. Coast Guard 13th District Headquarters Marine Environmental Protection Officers Seattle, WA	LCDR Gordon Lt. Dody Lt. Riorden	Seattle, Puget Sound, Portland, Columbia River
U. S. Coast Guard Captain of Port Seattle, WA	Lt. Gregory	Seattle, Puget Sound
Port of Port Angeles Port Angeles, WA	Jerry Hendricks Joe Faires	Straits of Juan de Fuca - Debris handling
M. V. Coho Between Port Angeles and Victoria, B.C.	Capt. Lewis	Straits of Juan de Fuca, Puget Sound
R.B.H. Cybernetics Victoria, B.C.	Norm Sewell	- Skimmer, debris handling

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
Marine Oil Pickup Service Seattle, WA	Mike Livingston Barry Paulsen	Seattle, Puget Sound, Columbia River - Booms and skimmers, debris handling
Army Corps of Engineers Seattle District Seattle, WA	Don Thuring, Operations	Seattle, Puget Sound - Debris handling
Willamette-Western Portland, OR	Keith Roberts	Portland, Columbia River - Booms, debris handling
Standard Oil Portland, OR	John Hartup	Portland, Columbia River - Booms, debris handling
Grays Harbor Port Authority Grays Harbor, WA	Mr. van Deene, Chief	Grays Harbor, Washington Coastal
Army Corps of Engineers Portland District Portland, OR	Chuck Galloway Mike Hay Jack Bechly	Columbia River, Oregon Coastal - Debris handling
Port of Portland Portland, OR	Carl Fropp	Portland, Willamette - Skimmers
Army Corps of Engineers Northwest Division Portland, OR	Jake Schmitt, Operations	- Debris handling
Army Corps of Engineers Sausalito, CA	W. Angeloni	San Francisco Bay - Debris handling

TABLE A. (Continued)

Organization and Location	Person Contacted	Location of Debris Information Obtained - Type of Equipment Information Obtained
U. S. Coast Guard Pacific Strike Team San Francisco, CA	LCDR Wiechert	San Francisco Bay, California Coastal - Debris handling, booms and skimmers
Clean Bay, Inc. Concord, CA	Reece Norton	San Francisco Bay, California Coastal - Debris handling, booms and skimmers
Southern California Coastal Water Research Project Los Angeles, CA	W. Bascom	Southern California Coastal, Oregon, Washington Coastal
Long Beach Harbor Cleanup Boat, "Dipper" Long Beach, CA	Crew	Long Beach - Debris handling
Los Angeles Harbor Cleanup Boat, "Tina Maru" Los Angeles, CA	Crew	Los Angeles - Debris handling

APPENDIX B

INDIVIDUALS CONTACTED BY TELEPHONE

Appendix B contains the names, locations, and telephone numbers of individuals contacted by telephone during the study.

APPENDIX B

TABLE B. INDIVIDUALS CONTACTED BY TELEPHONE

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Colloid Chemical Co. Brockton, MA (615) 583-7850	H. Langermann	Booms
Pollution Booms, Inc. Avon, MA (615) 588-8800	Alan MacEachern	Booms
Quincy Adams Marine Basin, Inc. Quincy, MA (617) 471-2760	W. Ferry	Booms
JBF Scientific Corp. Burlington, MA (617) 273-0270	Ralph Bianchi	Skimmer
Ccastal Services, Inc. Braintree, MA (617) 848-4820	Ben Santacroce	Boston, New England Coastal - Debris handling, booms and skimmers
Massachusetts Division of Water Public Works Department Boston, MA (617) 727-4508	Tony Spadofora	Boston
Sunshine Chemical Corp. West Hartford, CT (203) 232-9227	Steve Kaufmann	Skimmers

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Metropolitan Petroleum Petro- chemicals Jersey City, NJ (201) 434-4451	Bill Wolf	Booms
Oil Recovery Systems Mineola, NY (516) 747-3457	Eric Lithen Charles Darcy	Skimmer
Army Corps of Engineers Baltimore, MD (301) 962-4646	Mr. Epstein	Baltimore - Debris handling
NOAA Rockville, MD (301) 496-8734	Robert Junghans	United States Coastal
Virginia Port Authority Norfolk, VA (703) 622-1671	Hugh Johnson	Norfolk Area
Army Corps of Engineers Hampton Roads, VA (804) 625-8201	Charles Brickner	
Ocean Systems, Inc. Reston, VA (703) 471-1310	Henry McKenna	Skimmers, booms

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Industrial Marine Service Norfolk, VA (804) 545-0692	Jim Parker	Norfolk, Chesapeake Bay, Baltimore - Booms and skimmers, debris handling
U. S. Coast Guard Marine Inspection Office Savannah, GA (912) 232-4321	LT Hersh (MEP)	Savannah
Army Corps of Engineers South Atlantic Division Atlanta, GA (404) 526-6742	Henry Bradley	Southeast Coastal
Georgia Ports Authority Savannah, GA (912) 964-1721	Bob Lane	Savannah
Environmental Protection Agency Atlanta, GA (404) 526-3931	Al Smith	Southeast Coastal - Booms and skimmers
Army Corps of Engineers Permits and Statistics Operations Division Savannah, GA (912) 233-8822	Steven Osvald	Savannah

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Goodyear Rockmart, GA (404) 684-7855	C. F. Logan	Booms
Environmental Protection Agency Solid Waste Information Retrieval (SWIRS) Washington, D.C. (202) 254-7506		United States Coastal
National Oceanographic Data Center Washington, D.C. (202) 426-9061		United States Coastal
Maryland Port Administration Baltimore, MD (301) 383-5700	Robert L. Nelson	Chesapeake Bay
State of Maryland Water Resources Department Baltimore, MD See phone numbers, next column	Mr. Silverman (301) 267-5846 Enforcement Division (301) 267-5551 Natural Resources Police (301) 267-1247 Warren Shelly (Waterways Improvements) (301) 267-5418	Chesapeake Bay, Baltimore

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Department of the Interior Water Resources Scientific Information Center Washington, D.C. (202) 343-8435	Mr. Lulick	United States Coastal
NOAA National Ocean Survey (N.O.S.) Rockville, MD See phone numbers, next column	Director of N.O.S. (301) 496-8204 Chief, Coastal Mapping (301) 496-8744 CDR Wesley Hull, Mr. Ramey Oceanography, Carl Fisher (301) 496-8274 LT Dick Moore (301) 496-8050 Mr. DiNardi	United States Coastal
Army Corps of Engineers Chief of Operations Washington, D.C. (202) 693-6858	Tom Blankenship	United States ports and rivers
Army Corps of Engineers Director, Comprehensive Studies of Water Resources Washington, D.C. (202) 693-7202	Carl Gaum	United States Coastal

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
NOAA National Marine Fisheries Service Washington, D.C. (202) 343-4881	Ms. Ann Weeks	United States general
Maritime Administration Department of Commerce Office of Ports and Intermodal Systems Washington, D.C. (202) 967-3548	Ken J. Randall	United States ports
Environmental Protection Agency Office of Water Programs Monitoring and Data Support Div. Washington, D.C. (202) 426-7792	Sam Conger	United States general
U. S. Coast Guard Jacksonville, FL See phone numbers, next column	CDR Sam S. Cavallaro (904) 791-3652 Pollution Investigation Officer (904) 791-2648	Jacksonville
Jacksonville Port Authority Jacksonville, FL (904) 633-5140		Jacksonville
Belcher Oil Company Miami, FL (305) 672-6801	Floyd Syrcle	Miami, Port Everglades - Debris handling, booms and skimmers

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
U. S. Coast Guard Miami, FL See phone numbers, next column	ENS LaPorte (305) 350-5276 Percy Norwood (305) 672-2021	Miami, Port Everglades
Danmark, Inc. Miami, FL (305) 573-0610	Harold Daniels	Miami, Port Everglades - Debris handling, booms and skimmers
JPS Equipment, Inc. Port Everglades, FL (305) 584-8387	Bill Parnell	Boom
Army Corps of Engineers District New Orleans, LA (504) 865-1121	Mr. Garrett, Hydrology Mr. Mire, Navigation	Mississippi
Port of Galveston Galveston, TX (713) 765-9321	Chuck DeVoy	Galveston
National Maritime Research Center Galveston, TX (713) 744-7141	Mr. Crook Mr. Fink	Gulf Coast
Spiltrol Houston, TX (713) 461-4477	Bill Huskey	Skimmer

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
San Diego Unified Port District San Diego, CA (714) 291-3900	Mr. Forrest, Engineering	San Diego
Muehleisen Manufacturing Co. El Cajon, CA (714) 442-2571	Chuck Summers	Booms
Submarine Engineering Associates Coronado, CA (714) 435-5252	Dick Johnston	Booms
Ocean Design Engineering Corp. Long Beach, CA (213) 432-8983	Don Hall	Skimmers
Sandvik Conveyors, Inc. Los Angeles, CA (213) 723-9116	Olof Hellsund	Skimmers
Skim, Inc. Los Angeles, CA (213) 263-3829	George Stebbins Jim Stebbins	Skimmer
Johns Manville Long Beach, CA (213)834-6471	Al Moore	Booms
Clean Seas, Inc. Santa Barbara, CA (805) 963-3488	Mr. Wade	Southern California Coastal - Booms and skimmers

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Lockheed Sunnyvale, CA (408) 742-6756	Erme Agee	Skimmers
Army Corps of Engineers Division Office Portland, OR (215) 884-5583	Jake Schmitt, Project Operations	Debris handling
Army Corps of Engineers Portland District Office Portland, OR (503) 777-4441	Bob Hopman, Ext. 371	Columbia River, Oregon Coastal
Portland Oil Spill Cooperative Portland, OR (503) 223-4161	John Hartup	Columbia River; Portland, OR; Willamette River - Booms, debris handling
Esco Corp. Portland, OR (503) 228-2141	Jim Corso	Booms
Marine Oil Pickup Service Seattle, WA (206) 682-4898	Barry Paulsen	Seattle, Puget Sound, Portland - Booms and skimmers, debris handling
Army Corps of Engineers Chief of Navigation and Flood Control Seattle, WA (206) 442-4000	Don Thuring	Seattle, Puget Sound - Debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
MARCO Seattle, WA (206) 285-3200	Bill Lerch	Skimmers
Ice Harbor Dam (Snake River) Walla Walla, WA (509) 547-7781	Paul Winberg	Debris handling
Pacific Towboat Everett, WA (206) 252-4131	Skip Brown	Puget Sound - Debris handling
American Tugboat Co. Everett, WA (206) 252-1117	Dick Hallenger	Puget Sound - Debris handling
Everett Plywood Everett, WA (206) 252-4137	Calvin Lloyd	Debris handling
Western Forest Industries Assoc. Portland, OR (503) 224-5455	Joe McCracken	Debris handling
Grand Coulee Dam WA (509) 525-5500	Mr. Eaton	Debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Port Gardner Mill Co. Everett, WA (206) 252-8989	Howard Dorsey	Debris handling
Port of Bellingham Bellingham, WA (206) 734-9110	Mr. Adams	Bellingham
Grays Harbor Port Authority Grays Harbor, WA (206) 533-3620	Gerard van Deene	Grays Harbor, Washington Coastal
R.B.H. Cybernetics Victoria, B.C., Canada (604) 658-5713	Norm Sewell	Skimmers, debris handling
Port of Port Angeles Port Angeles, WA (206) 457-8527	D. G. (Jerry) Hendricks	Straits of Juan de Fuca - Debris handling
Bennett Pollution Control North Vancouver, B.C., Canada (604) 682-1027	John Bennett	Boom
Army Corps of Engineers Omaha District Omaha, NE (402) 221-4136	Mr. Mason	Debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
NOAA - National Marine Fisheries Service Marine Resources Monitoring and Prediction Program Narragansett, RI (401) 789-9326	Ken Sherman	Atlantic and Pacific Oceans
Environmental Protection Agency Denver, CO (303) 837-2468	Dick Jones	Debris handling, booms and skimmers
Army Corps of Engineers Louisville, KY (502) 582-5640	Col. Falla	Debris handling
Aquamarine Co. Waukesha, WI (414) 547-0211	Braite Bryant	Debris handling
Oil Skimmers, Inc. Cleveland, OH (216) 237-6181	Craig Riley	Skimmers
Trelleborg Rubber Co. Ohio (216) 248-8600		Boom
Acme Products Co. Tulsa, OK (918) 836-7184	H. E. Stanfield	Skimmers and booms

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Uniroyal, Inc. Mishawaka, IN (219) 255-2181	Ron DePastine Mr. Cottrill	Booms and skimmers
The Pearson Bros. Co. Galva, IL (309) 932-2191		Skimmers
Grafton Boat Works Grafton, IL (618) 786-3371	Bill Evans	Debris handling
Camran Corporation Seattle, WA (206) 285-0700	Carl Weholt	Debris handling
Air Pollution Control Products, Inc. Richmond, VA (805) 746-4535	Bill Taylor	Debris handling
Mechtron, Environmental Control Products Orlando, FL (305) 843-9890	John Shand	Debris handling
Melroe Equipment Company Gardena, CA (213) 324-6684	Richard Fadness	Debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Syntron Los Angeles Sales Company Los Angeles, CA (213) 770-0634	John Woodward	Debris handling
U. S. Coast Guard M.E.P., 12th Coast Guard District San Francisco, CA (415) 556-0715	CDR Gordon Dickman	San Francisco, California Coastal - Booms and skimmers, debris handling
Nelson Log Bronc Corporation Coos Bay, OR (503) 269-5101	Jack Wilsky	Debris handling
Gene Brown Boats Seattle, WA (206) 624-7894	Gene Brown	Debris handling
Civil Engineering Laboratory Naval Construction Battalion Center Port Hueneme, CA (805) 982-4191	Jack Williams	United States general - Debris handling
Washington Iron Works Seattle, WA (206) 623-1292	Mr. Dickinson	Debris handling
Raygo Wagner Portland, OR (503) 252-5531	Francis Hegmeyer	Debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Mar-Hook Company Aberdeen, WA (206) 533-3210	John D. Mitchell	Debris handling
Marathon LeTourneau Company Longview, TX (214) 753-4411	Mr. McKuen	Debris handling
U. S. Coast Guard Group Portland, ME (207) 799-5531	CAPT Donald McCan	Portland, ME; Maine Coastal
U. S. Coast Guard Group Southwest Harbor, ME (207) 244-5517	LTJG Ernie Blanchard	Maine Coastal
Captain of the Port of Portland Portland, ME (207) 799-5531	ENS Don Riley	Portland, ME
Research Institute for the Gulf of Maine Portland, ME (207) 773-2981	Edward Shenton	Maine Coastal
Seacoast Ocean Services Portland, ME (207) 774-2111	Bob Madsen	Portland, New England Coastal - Booms and skimmers, debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Army Corps of Engineers Boston, MA (617) 894-2400	Mr. Fistel, Ext. 351	Boston - Debris handling
U. S. Coast Guard Chief, Marine Environmental Protection (MEP) Boston, MA (617) 223-6915	Mr. Jones (for CAPT Robert Brazier)	Boston
U. S. Coast Guard Group Woods Hole, MA (617) 548-1700	ENS Gene Proulx	New England Coastal
Coastal Services Braintree, MA (617) 848-4820	Ben Santacroce	Boston, New England Coastal - Booms and skimmers, debris handling
Debris Cleanup Service Boston, MA (617) 242-1993	Arthur Fournier	Boston
Environmental Protection Agency Boston, MA (617) 223-7265	John Conlon	New England Coastal
Port Safety Station Boston, MA (617) 223-6980	LT Dave Blomberg	Boston

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Woods Hole Oceanographic Institution Woods Hole, MA (617) 548-1400	Mrs. Nancy Simmons Document Library	United States general
American Society of Civil Engineers New York, NY (212) 752-6800	Mr. Ameron (Ext. 381)	United States general - Debris handling
Army Corps of Engineers New York, NY (212) 264-9021	Lou Pinata (talked to Dennis O'Hasky)	New York - Debris handling
U. S. Coast Guard Oil and Hazardous Materials New York, NY (212) 264-8753	Mr. Hobbie (for LCDR Harbison)	New York - Debris handling
EPA Philadelphia, PA (215) 597-9898	Bob Kaiser	Philadelphia - Booms, debris handling
American Association of Port Authorities Washington, D.C. (202) 638-6263	Mr. Donald Allen	United States ports
Army Corps of Engineers Baltimore, MD (301) 962-4646	Mr. Edwards	Baltimore - Debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Army Corps of Engineers Washington, D.C. (202) 693-6995	Mr. Millard	United States general
EPA Division of Oil and Hazardous Materials Washington,D.C. (202) 426-8703	Hal Snyder	United States general
National Academy of Sciences Washington, D.C. (202) 961-1861	Mr. William Robertson	Atlantic, Pacific and Gulf of Mexico
U. S. Coast Guard Fifth Coast Guard District Portsmouth, VA (703) 393-9611	Lt.Stowe, Coordinator	Norfolk
Army Corps of Engineers Savannah, GA (912) 233-8822	Mr. Osvald	Savannah
Skidaway Institute of Oceanography Savannah, GA (912) 352-1631		United States general
U. S. Coast Guard Miami, FL (305) 350-5611	ENS La Porte	Miami/Port Everglades

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Rosenstiel School of Marine and Atmospheric Science University of Miami, FL (305) 350-7207		United States general
U. S. Coast Guard New Orleans, LA (504) 527-6296	LT Ford	Mississippi
U. S. Coast Guard Port of New Orleans, LA (504) 527-7101	LT McCall	Mississippi
Port of New Orleans, LA (504) 522-2511	Mr. Hendricks Engineering Dept.	Mississippi
U. S. Coast Guard Port of Houston, TX (713) 226-4804	LT Clark	Houston - Booms
Port of Houston, TX (713) 672-8221	Mr. Lou Brown	Houston - Debris handling
Corpus Christi Area Oil Spill Assoc. (512) 882-8512	Mr. Harry Franklin	Corpus Christi - Skimmer
Port Director, Nueces County Corpus Christi, TX (512) 882-5633	Mr. David Halpenstern	Corpus Christi

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Oceanic Library and Information Center La Jolla, CA (714) 292-1515	Paul Janensch	United States general
Scripps Institution of Oceanography La Jolla, CA (714) 453-2000	Miss Gean Munroe Reference Librarian	United States general
Hancock Foundation Library University of Southern California Los Angeles, CA (213) 746-6005		United State general
Petroleum Industry Coastal Emergency Cooperative (PICE) Long Beach, CA (213) 435-5306	Capt. Bush	L.A./Long Beach - Booms and skimmers
Army Corps of Engineers San Francisco Bay (415) 556-2404	Bob Thomas	San Francisco Bay - Debris handling
Clean Bay, Inc. Oakland, CA (415) 685-2800	Forrest Smith Reese Norton	San Francisco Bay, California Coastal - Booms and skimmers, debris handling
U. S. Coast Guard, 12th District San Francisco, CA (415) 556-0715	CDR Dickman Commander, MEP	San Francisco Bay, California Coastal - Booms and skimmers, debris handling

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
EPA San Francisco, CA (415) 556-7859	Harold Takenaka	California Coastal
EPA San Francisco, CA (415) 556-7550	Ronald Clawson	California Coastal
Woodward-Envicon, Inc. San Francisco, CA (415) 956-7070	J. D. Sartor	Skimmers
Army Corps of Engineers Portland, OR (503) 221-3756	Mr. Maury Larsen Frank Bertenchamps	Columbia River - Debris handling
Port of Portland, OR (503) 233-8331	Carl Propp	Portland - Skimmers
Army Corps of Engineers Hydrology Office Walla Walla, WA (509) 525-5500	Mr. Lanham (Ext. 339)	Columbia River - Debris handling
Battelle-Northwest Richland, WA (509) 946-2432 (509) 946-2150 (509) 946-2108 (509) 946-2407 (509) 946-2229	P. C. Walkup Chuck Henniger Palmer Peterson Don Rasmusson Ward Swift	United States general - Skimmers

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
CH_2M-Hill Seattle, WA (206) 455-0500	Bill Dehn	Seattle
City of Seattle Harbor Patrol (206) 583-2179		Seattle
U.S. Coast Guard Seattle, WA (206) 624-2902	LCDR Gordon, MEP (Ext. 343)	Seattle, Puget Sound, Washington Coastal
EPA Seattle, WA (206) 442-1263	James Willman	Washington Coastal
Marine Oil Pickup Service Seattle, WA (206) 682-4898	Mr. Trig Enger	Seattle, Puget Sound, Portland - Booms and skimmers, debris handling
Municipality of Metropolitan Seattle (206) 284-5100	Rod Stroope	Seattle
Oil Spill Co-op Seattle, WA (206) 624-7014	Mr. Beherens	Seattle, Puget Sound - Booms and skimmers
Stevens-Thompson-Ruynon Seattle, WA (206) 623-6350	Ron Owes	Seattle

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
U.S. Coast Guard, 2nd District St. Louis, MO (314) 622-5053	LT Allen (for CDR Webb) Coordinator	Debris handling
EPA Kansas City (816) 374-4464	W. L. (Pete) Banks	Debris handling
EPA Dallas, TX (214) 749-2591	Wallace Cooper	Texas Coastal
EPA Atlanta, GA (404) 526-3931	Al Smith	Southeast Coastal
EPA Edison, NJ (201) 548-3347	Howard Lamp'l	Northeast Coastal - Skimmers and Booms
Army Corps of Engineers Honolulu, Hawaii (808) 543-2871	Mr. Jones	Hawaii
State Harbors Division Operations Dept. Honolulu, Hawaii (808) 548-6255	Capt. Cook Mr. Thompson	Hawaii

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Naval Facilities Engr. Command Environmental Branch Honolulu, Hawaii (808) 471-3948	Mr. Lau	Hawaii
Shop 02 U.S. Navy Pearl Harbor, Hawaii (808) 474-1168	Crew of "Juicy Lucy"	Pearl Harbor - Debris handling
Slickbar Inc. Westport, Connecticut (203) 226-6343	Mr. Millard Smith	Booms and skimmers
Envirometrics, Inc. Alsip, Illinois (312) 264-6600	Mr. Ray Winters	Booms
Marsan Corporation Elgin, Illinois (312) 741-9047	Mr. John Harper	Booms
American Marine Inc. Merritt Island, Florida (305) 363-5783	Mr. Charlie Miller	Booms
Innova Corporation Seattle, Washington (206) 524-4888	Ms. Marta Brakke	Booms

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Metropolitan Petroleum Petrochemicals Company, Inc. Jersey City, New Jersey (201) 434-4451	Mr. Bill Wolf	Booms
Sorbent Sciences Corporation Covina, California (213) 339-1259	Mr. Milton Gray	Booms and skimmers
Pacific Pollution Control San Francisco, California (415) 843-5602	Mr. Neal Tanksley	Booms
Kepner Plastics Fabricators, Inc. Torrance, California (213) 772-3246	Mr. Frank Meyers	Booms
3M Company New Business Ventures Division St. Paul, Minnesota (612) 733-4043	Mr. John Evert	Booms
Conweb Minneapolis, Minnesota (612) 378-0030	Mr. Clare Swanson	Booms
Centri-Spray Corporation Livonia, Michigan (313) 534-7000	Mr. Neil Skelly	Skimmers

TABLE B. (Continued)

Organization and Location Telephone Number	Person Contacted	Location of Debris Information or Type of Equipment Information Obtained
Pollution Booms, Inc. (formerly Slickguard, Inc.) Avon, Massachusetts (617) 588-8800	Mr. Alan MacEhern	Booms

APPENDIX C

COMPANIES WHICH FURNISHED POSSIBLE DEBRIS-HANDLING EQUIPMENT INFORMATION BY MAIL

Appendix C contains the names and addresses of companies that furnished information in reply to written debris-handling equipment inquiries.

APPENDIX C

COMPANIES WHICH FURNISHED POSSIBLE DEBRIS-HANDLING EQUIPMENT INFORMATION BY MAIL

Link-Belt Material Handling Equipment Division
300 West Pershing Road
Chicago, Illinois 60609

Syntron Division
Homer City, PA 15748

Hiab Hydraulics, Inc.
3404 Lancaster Pike
Wilmington, Del. 19805

Liftex Slings, Inc.
Box 368-TR
Libertyville, Ill. 60048

The Ehrsam Company
300 N. Cedar
Abilene, Kansas 67410

Clark Equipment Company
Melroe Division
Gwinner, North Dakota 58040

Kysor/Brucio Div. of Kysor Industrial Corp.
1752 Alpine, N.W.
Grand Rapids, Mich. 49504

Mack Welding Company, Inc.
8718 Arbor St.
Duluth, Minn. 55808

Jeffery Manufacturing Co.
956 N. 4th St.
Columbus, Ohio 43216

Tate Systems Division
705 South St.
Beatrice, Nebraska 68310

Link-Belt Material Handling Systems Division
3400 Walnut St.
Colmar, PA 18915

Materials Handling Systems, Inc.
69 Grassmere Ave.
West Hartford, Conn. 06110

Materials Handling Equipment Co.
2619-59 N. Normandy Ave.
Chicago, Ill. 60635

The Coldwell Company, Inc.
5049 26th Ave.
Rockford, Ill. 61110

Union Steel Products Co.
242 Berrien St.
Albion, Mich. 49224

Rowa Iron Works, Inc.
1419 Woodland Ave.
Detroit, Mich. 48211

Magnesium Fabricators Inc.
Box 45 TR
Linwood, Mich. 48634

Hoeltge, Inc.
5238 Crookshank Rd.
Cincinnati, Ohio 45238

Speed King Co., Inc.
P.O. Box 1438, TR-72
Dodge City, Kansas 67801

McDowell - Wellman Engineering Co.
113 St. Clair Ave., N.E.
Cleveland, Ohio 44114

APPENDIX C (Continued)

Con-Vey Internationl, Inc.
5318 S.W. Westgate Dr.
Portland, Ore. 97221

Heyl and Patterson, Inc.
800 Seven Parkway Center
Pittsburgh, PA 15220

Empire Engineering Co.
Pasadena, CA

Peerless Trailer and Truck Service
P.O. Box 447-T
Tualatin, Ore. 97062

McGinnes Manufacturing Co.
P.O. Box 12671-TR
Houston, Texas 77017

Solids Comersion Systems Corp.
Hopkins, Minn.

APPENDIX D

ALPHABETICAL DEBRIS-TYPE LIST

The following appendix contains an alphabetical listing of the debris items observed during the study.

TABLE D. ALPHABETICAL DEBRIS-TYPE LIST

Debris Type	Comments
Algae	
Bark	From trees and from trees in log rafts
Baseball bats	
Baseballs	
Birds (dead)	Seagulls, sparrows, etc.
Boards	
Boats	Both pieces and whole (including derelicts)
Bottles	
Boxes	Metal
Branches	From trees and bushes
Brush	From banks of creeks, rivers, etc.
Camels	
Cans	
Canvas	
Cardboard boxes	
Cellulose fibers	
Charcoal	
Cigarette filters	
Clothing	Shirts, skirts, pants, socks, coats, etc.
Coconuts	
Cofferdams	Whole and in pieces
Confetti	Found in quantity around passenger terminals
Cork	Pieces, small sheet, and blocks
Corn cobs	
Counterfeit money	
Dolphins	And pieces of dolphins
Dunnage	

TABLE D. (Continued)

Debris Type	Comments
Eel grass	
Egg crates	
Egg cartons	
Eyebrow-pencil heads	
Feathers	
Fences	Pieces of whole fences
Fish	From red tide, algae kills
Fish boxes	
Fish heads	
Fishing line	
Flares	Burnt
Floating grass and mud	
Floating grease	
Floating wax	
Floats	Both fishing and mooring
Flotsam and Jetsam	
Front porches	
Fruit (floating)	From trees and lost cargo
Gloves	Canvas and rubber
Grain	
Grass	
Hatch covers	
Hawsers	
Hay	
Hemp	
Horses and cows	Dead
Houseboats and floathouses	

TABLE D. (Continued)

Debris Type	Comments
Household furniture	
Houses	
Human bodies	
Husks	Corn and rice
Hyacinth	
Inner tubes	
Jellyfish	
Kelp	
Kelp seeds	
Latex	
Leaves	
Life jackets	
Life preservers	
Life rings	
Light bulbs	
Lilly pads	
LNG bottles	Liquefied natural gas
Lobster pots	
Log rafts	
Logs	
Luggage	
Marsh weeds	
Metal structures	Floating aluminum and steel fabricated items
Mice	
Milk cartons	
Milk crates	

TABLE D. (Continued)

Debris Type	Comments
Nets	Fishing and cargo handling
Nylon	Pieces and objects
Oars	
Oil drums	55-gallon, typically
Paddles	
Paint and lacquer cans	
Paint brushes	
Pallets	
Palm fronds	
Paper	Newspaper, craft paper
Paper cups	"Dixie" cups
Peat moss	
Pelts	Animal
Pens	Ballpoint, etc.
Perlite	Associated with kelp processing
Pianos and organs	
Pieces of leather	
Pieces of rubber	
Pieces of vessels	
Pier pieces	
Pilings	
Pine needles	
Ping-Pong balls	
Planks	
Plastic bags	
Plastic bottles	
Plastic buckets	

TABLE D. (Continued)

Debris Type	Comments
Plastic cigar tops	
Plastic combs	
Plastic cups	Rigid type
Plastic eating utensils	
Plastic hair curlers	
Plastic pieces	
Plastic six-pack holders	
Plywood sheets	
"Pop tops"	
Popcycle sticks	
Propane bottles	
Prophylactics	
Pulp fibers	
Rags	
Railroad ties	
Rats	
Reeds	
Refrigerators	Also freezers
Resin beads	
Roots	
Rope	
Rubber bands	
Rubber thong sandals	Also called "Zoris"
Saw grass	
Sawdust	
Scaffolding	
Seals	

TABLE D. (Continued)

Debris Type	Comments
Seaweed	
Seeds	
Sewer floatables	Grease, solids, etc.
Sheet plastic	
Sheets	Bedding sheets
Shoe laces	
Shoes	Leather, canvas, and rubber
Sinker boats	
Slash (from logging)	Remains of trees left from logging operations
Sleeping bags	Rolled and unrolled
Small animals	Dead dogs, cats, etc.
Soap cartons	
Sorbent pads	
Sorbents	Bulk type
Sponges	
Sticks	
Straw	
Straws	Drinking straws
Styrene coolers	Whole and in pieces
Tallow	
Tar	
Telephone poles	
Tennis balls	
Timbers	
Tires	
Toothbrushes	
Towels	
Toys	Including pieces of toys

TABLE D. (Continued)

Debris Type	Comments
Tree stumps	
Tree trunks	
Turtle grass	
Visqueen sheets	Plastic sheets used for covering ship cargo
Wax	
Weeds	
Wood chips	

APPENDIX E

DEBRIS CATEGORIZATION

Appendix E contains listings of debris items that have been classified under eight general debris categories.

TABLE E. DEBRIS CATEGORIZATION

Category I - General Wood Items

Small	Medium	Large
Bark pieces	Bark pieces	Boards
Boards	Baseball bats	Camels
Branches	Boards	Dolphins (pieces of)
Brush	Branches	Logs
Popsicle sticks	Brush	Oars
Sawdust	Camels	Pier pieces
Slash	Dolphins (pieces of)	Pilings
Sticks	Oars	Planks
Wood chips	Paddles	Scaff[illegible]
	Pier pieces	Tele[illegible]
	Planks	Timbers
	Railroad ties	Tree stumps
	Roots	Tree trunks
	Scaffolding	
	Slash	
	Sticks	
	Tree stumps	
	Tree trunks	

TABLE E. (Continued)

Category II - Non-Rigid Shapes	
Small	Large
Birds	Cows
Cardboard boxes	Horses
Fish	Human bodies
Fish heads	Palm fronds
Floating grass and mud clumps	Seals
Inner tubes	Tires
Jellyfish	
Life jackets	
Mice	
Rats	
Rolled sleeping bags	
Rubber gloves	
Shoes	

TABLE E. (Continued)

Category III - Rigid Shapes		
Small	Medium	Large
Charcoal pieces	Cork blocks	Boats
Cigarette filters	Corn cobs	Cofferdams
Corks	Egg cartons	Front porches
Eyebrow-pencil heads	Egg crates	Houseboats
Flares	Fish boxes	Household furniture
Floats	Flares	Houses
Grain	Floats	Log rafts
Kelp seeds	Household furniture	Metal structures
Nylon pieces	Life preservers	Organs
Plastic cigar tips	Life rings	Pianos
Plastic eating gear	Lobster pots	Pieces of boats
Plastic hair curlers	Luggage	Pieces of cofferdams
"Pop-tops"	Metal boxes	Refrigerators
Resin beads	Metal structures	
Seeds	Milk crates	
Toys	Nylon objects	
	Paint brushes	
	Pens	
	Pieces of boats	
	Pieces of cofferdams	
	Plastic buckets	
	Plastic combs	
	Plastic cups (rigid)	
	Styrene coolers	
	Tires	
	Toothbrushes	
	Toys	

TABLE E. (Continued)

Category IV - Flexible Sheets	
Small	Large
Canvas	Canvas
Clothing	Clothing
Cork sheets	Cork sheets
Corn husks	Latex (solid form)
Counterfeit money	Paper
Gloves (canvas or cloth)	Pelts
Hyacinth	Pieces of leather
Latex (solid form)	Pieces of rubber
Leaves	Plastic bags
Lily pads	Rags
Paper	Sheet plastic
Pelts	Sheets (bedding)
Pieces of leather	Sleeping bags (unrolled)
Pieces of rubber	Sorbent pads
Plastic bags	Towels (bath)
Plastic six-pack holders	
Prophylactics	
Rags	
Rubber thongs	
Sheet plastic	
Sorbent pads	
Towels (face)	

TABLE E. (Continued)

Category V - Rigid Sheets		
Small	Medium	Large
Bark	Bark	Fences
Pieces of styrene	Hatch covers	Hatch covers
Plastic pieces	Pallets	Pallets
Plywood pieces	Pieces of fence	Pieces of scaffolding
	Pieces of scaffolding	Plywood panels
	Pieces of styrene	
	Plastic pieces	
	Plywood sheets	

TABLE E. (Continued)

Category VI - Amorphous Material
Algae
Bulk sorbents
Floating grease
Floating wax
Peat moss
Perlite
Rice husks
Sewer floatables
Tallow
Tar
Wax

TABLE E. (Continued)

Category VII - Filamentous Pieces	
Individual Pieces	Groups of Pieces
Cellulose fiber	Cellulose fibers
Confetti	Confetti
Drinking straw	Eel grass
Eel grass	Feathers
Feather	Fishing line
Fishing line	Grass
Grass	Hay
Hawser	Hemp
Hay	Kelp
Hemp	Marsh weeds
Kelp	Nets
Marsh weed	Pine needles
Nets	Pulp fibers
Pulp fiber	Reeds
Reed	Rope
Rope	Saw grass
Rubber band	Seaweed
Saw grass	Shoe laces
Seaweed	Straw
Shoe lace	Weeds
Straw	
Turtlegrass	
Weed	

TABLE E. (Continued)

Category VIII - Special Cases	
Circular or Spherical-Surfaced Objects	Fabricated Paper Items
Baseballs	Milk cartons
Coconuts	Paper cups
Fruit	Soap cartons
Glass bottles	
Light bulbs	
LNG bottles	
Oil drums	
Paint and lacquer cans	
Ping-Pong balls	
Plastic bottles	
Propane bottles	
Tennis balls	

APPENDIX F

REGIONAL DEBRIS DESCRIPTIONS

Appendix F contains regional descriptions of the types and quantities of debris which are found in the various areas researched during the course of this study. Past local experience with debris in oil spills is given where possible.

TABLE F. REGIONAL DEBRIS DESCRIPTIONS

Debris Encountered by Category	Description
	New England Region - Northern New England Coast
General Wood Items	Wooden debris is found scattered throughout this region. Tree limbs, trunks, roots, and branches due to logging activities and to natural erosion come down the rivers into the ocean during the spring, summer, and early fall. The higher nominal water level in the spring, caused by snowmelt and ice thaw, brings down the highest continuing seasonal quantity of wooden material. The quantity in most of the Northeast during normal periods consists of periodic items of wood which enter the offshore areas one piece at a time. Generally, the frequency of occurrence of wood on the water will increase as the water level in major rivers increases. The size of wood encountered can vary from twigs up to occasional entire trees. When a severe storm such as a hurricane occurs, the debris quantity found in the rivers can increase drastically. Material that is normally stranded on river banks above the waterline will come down during these periods. Erosion and breakage of tree limbs is also highest during and after severe storm periods. Concentrated patches of wood consisting of small, medium, and large items can be expected on the water after a hurricane. The wooden debris that enters the offshore area tends to collect on the few sandy beaches that are found in the region. The debris will normally be stranded on the

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	beach above the high-tide line and would come off in quantity only when flood tides and offshore winds occur. As a general note, the quantity of wood that is found in this region is minimal when compared to port areas in the northwest United States.
Non-Rigid Shapes	Occasional fish kills, due to natural effects or pollution, occur in the area. During these times, concentrations of dead fish can be found floating on the surface.
Rigid Shapes	Fishing floats, lobster pots, and fish boxes of various sizes are found floating in the area. They are usually found one at a time.
Flexible Sheets	Leaves are found floating in nearshore areas, especially during autumn months. They can be found completely covering the surface of some coves, eddies, and bays in the fall.
Filamentous Pieces	Eel grass, marsh grass, and seaweed are found in very large quantities in this region. To a lesser extent, straw is also found in certain locations. Concentrated areas of dead material are found in back bays, marshes, and on beaches each fall. The same material may be driven off the beaches and out of marshes when spring high water or flood tides and offshore winds occur together.

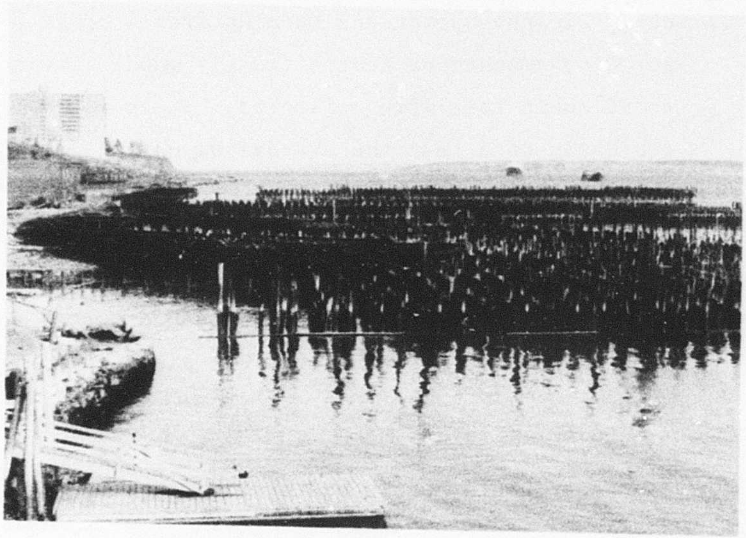
TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	Another source of loose floating material is the kelp and eel grass that is killed or contaminated during a spill by the oil. This material is usually collected with the oil and can, in areas of heavy concentration, present a handling problem. The quantity of material mixed with the oil on the water during a medium spill can be estimated to be 25 to 500 percent of the amount of oil recovered. An extreme example of the quantity of vegetation that can occur in a small spill in this region is the Piscataqua River spill in Portsmouth, New Hampshire. 1,000 to 1,500 gallons of No. 6 fuel oil were recovered. An estimated 60 tons of oil-soaked eel grass had to be recovered with the oil(1).
New England Region - Southern New England Coast	
General Wood Items, Non-Rigid Shapes, Rigid Shapes	Generally, the same as Northern New England Coast.
Filamentous Pieces	This area is similar to the Northern New England area except that the concentration of seaweed is slightly

(1) Conversation with J. Conlon, of Environmental Protection Agency, Boston Office (November 27, 1973).

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	less and the concentration of marsh grass is slightly more. The total quantity of these materials that could be expected in a spill is about the same. Another local source of material in an area can be debris (mostly dead seaweed and marsh grass) that has been deposited on unused beaches. The debris will come off the beach during flood tides and offshore winds. As this area has much more beach area than northern New England, the total quantity of material floated off the beaches in these conditions in a large spill will be greater.
	<u>New England Region - Portland Harbor</u>
General Wood Items	Timbers, pilings, boards, pieces of piers, planks, and other manufactured pieces of wood are found floating in the Portland Harbor area. Small, medium, and large pieces occur in approximately equal distributions. The sources of this debris are derelict vessels and dilapidated piers which collapse or decay causing wood to enter the water. A burned out pier which is a source of large wood pilings is shown in Figure F-1. The quantity of wood that is found in Portland Harbor is moderate relative to other Northeast ports. The amount



1101-73/F-1

FIGURE F-1. BURNED OUT PIER IN PORTLAND, MAINE

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	normally present can be estimated from a summer debris cleanup project undertaken in the Harbor in 1968[1]. In daily cleanup operations ranging from 4 hours to 8 hours per day, amounts of debris (mostly wood) varying from 5 to 50 cubic feet were collected. It is estimated from the daily data that the average amount of wood picked up daily was 25 cubic feet. This amount of wood could be expected in a small spill. In a medium or large spill, amounts one or two orders of magnitude larger could be expected. The material would be concentrated in some areas of the Harbor and found one piece at a time in others.
Rigid Shapes	Pieces of boats, whole boats, floats, and other discrete pieces could be expected to be floating in the Harbor.
Filamentous Pieces	Amounts of marsh grass, seaweed, straw, leaves, and other similar material are found in the Portland Harbor area. The quantity on the water is greatest during the fall and spring. Large fall concentrations occur because of the amount of material that dies with the onset of cold weather. This material tends to stay on the water until the wind drives it ashore. The large spring concentrations occur because the high water brings dead material off of the high water line of the shore.

(1) Letter of October 31, 1968, from K. Otenti, of the Neighborhood Youth Corps of Portland, to B. Langlois, Chairman of the Portland Harbor Pollution Abatement Committee.

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	The concentrations of the material discussed above can be quite heavy. In some small spills in the Portland area, 50 percent of the recovered material was debris. Most of this material consisted of grass and seaweed.
Special Cases	Oil drums are frequently encountered floating in the Portland Harbor area. At least one or two would be encountered in a medium sized spill.
	New England Region - Boston Harbor Area
General Wood Items	Most of the floating debris found in the Boston Harbor area is wood. Accordingly, available quantity information is listed under this catagory even though objects other than wood items are found. Wood and other debris come from one of several sources--illegal dumping, dilapidated shorefront structures, wrecked vessels, and shorefront dumps found around the area. The illegal dumping activities are estimated to contribute 45 to 50 percent of the total amount of floating material. The dilapidated shorefront structures and wrecked vessels cause most of the remaining debris. Dumps are a minor source of debris[1]. There

(1) Department of the Army, New England Division, Corps of Engineers, "Boston Harbor (Debris Study), Massachusetts, Survey (Review of Reports)" (July 1973).

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	are 186 wholly dilapidated and 105 partially dilapidated waterfront structures in this area. The structures are estimated to contain 3.25 million cubic feet of wood that could eventually find its way into the Harbor. The 1973 Corps report also lists 96 derelict vessels in the Harbor(1). Estimates of the mix of large, medium, and small debris found in the Boston area were quoted by A. Fournier, who operates the Corps-sponsored harbor cleanup activity. Percentages normally found, by weight, are -- large, 65 percent; medium, 20 percent; and small, 15 percent. Estimates of the quantity of debris found in the Boston area are also estimated in Reference 1. The amount of debris stranded on the shoreline and the material normally in the intertidal zone is quoted as a total of 75,000 cubic feet. Material not located on the shoreline or in the water, that could ultimately find its way into the Harbor as debris, is listed as 4 million cubic feet. Approximately 20,000 cubic feet of drift is estimated as being the normal amount of free-floating debris located in the intertidal zone during 1969. During severe storms, such as Northeasters, that have high water and unusual winds, as much as the entire

(1) Army Corps of Engineers, New England Division, op cit.

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	estimated 75,000 cubic feet of wood could be found floating off the shorelines. Most of the material in the Harbor is found concentrated underneath wharfs, in the corners of slips, or in backwater areas such as the Chelsea Creek area. The amount of material normally found floating in the open water of Boston Harbor will be much less. The small cleanup operation sponsored by the Corps normally picks up 160 cubic feet of material per day. The amount of material that could be expected in spills can be roughly estimated from the figures listed above. For a small spill, an amount of debris in the 20- to 200-cubic-foot range could be expected in open water. Against a sheltered-water area, with heavy debris concentration, this figure could double or triple. Medium spills could have debris quantities in the 500- to 2,000-cubic-foot range. Large spills could mean cleaning up 5,000 to 50,000 cubic feet of drift material. It is noted that the figures above are very subjective guesses and the amount of wooden debris that could be expected in a Boston Harbor spill could vary greatly from these quantities.
Non-Rigid Shapes	Dead fish are occasionally found floating in the Harbor area due to man-made or natural causes. Quantities of as

TABLE F. (Continued)

Debris Encountered by Category	Description
Non-Rigid Shapes (Continued)	much as several tons of fish are typical. Depending on winds and currents, the fish are concentrated or scattered in small patches of several fish each. Shoes, sponges, dead birds, cardboard boxes, tires, and other non-rigid shapes are found floating one at a time. Automobile tires are found in greatest quantity.
Rigid Shapes	Cigarette filters, toys, plastic parts, metal boxes, lobster pots, household furniture, pieces of boats, luggage, milk crates, paint brushes, refrigerators, and freezers are found an item at a time near the heavily populated shoreline areas.
Flexible Sheets	Small and large pieces of plastic sheet materials and articles of clothing are found throughout the Harbor area. Pieces of rubber, paper, plastic "six-pack" holders, towels, and rags are also found floating in small quantities (relative to the wood).
Amorphous Material	Some grease and wax is found floating in parts of the Harbor.
Filamentous Pieces	Pieces of rope, fishing line, and hausers are found floating alone or mixed with wood in the area.
Special Cases	Baseballs, glass and plastic bottles, light bulbs, oil drums, paint cans, and other cylindrical or round-

TABLE F. (Continued)

Debris Encountered by Category	Description
Special Cases (Continued)	surfaced objects are often found mixed with the wooden debris in the area. Milk cartons, paper cups, and soap cartons are also found in the same locations.
	New England Region - Providence Area
General Wood Items	The Providence River and Harbor areas and the Seekonk River areas of Rhode Island have a wood drift situation similar in nature to Boston, New York, and Philadelphia, but somewhat smaller in magnitude. The extent of the debris situation in the area and estimates of the cost to clean up debris were the subject of a Corps of Engineers report(1). In this reference, the sources of debris for the area are listed as-- waterfront structures, derelict vessels, loose onshore floatable debris, and shorefront dumps. The material from these sources that could ultimately become debris is estimated from Reference 1 as follows: Waterfront structures (133 dilapidated and 28 partially dilapidated structures) represent a potential 479,200 cubic feet of debris material; 57 wrecked vessels represent a potential 197,800 cubic feet of material; loose onshore material estimated as 70,500 cubic feet

(1) Department of the Army, New England Division, Corps of Engineers, "Providence River and Harbor/Seekonk River, Rhode Island, Survey" (June 1973).

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	over a 30-mile coastal zone; and 25 dumps for which no estimate of potential debris is given. Most of the above material is wood. Of the quantities listed above, the 70,500-cubic-foot shoreline figure could be used to estimate the quantity of wood that can be expected in a spill. In normal conditions, some fraction of the figure could be expected on the water in a spill. From the data from the Boston Area section, approximately 20,000 cubic feet could be estimated as normally being in the intertidal zone. Of this material, the amount involved in a spill would depend on the size of the spill. For descriptions of estimates for small, medium and large spills during normal weather conditions, the reader is referred to the Boston Area section discussion. During and after gales or hurricanes, however, the quantity of material on the water could be expected to double or triple. The structures and vessels that are sources contribute most of their wood during storms. No size definition is given in Reference 1, above, for the debris. However, the percentage composition of small, medium, and large debris will probably be similar to the Boston Harbor estimates (65 percent large, 20 percent medium, and 15 percent small).

(1) Army Corps of Engineers, New England Division, op cit ("Providence... Survey").

TABLE F. (Continued)

Debris Encountered by Category	Description
Other Categories	The debris that is classified under the categories other than wood can be expected to be similar to the Boston and New York situations except slightly smaller in magnitude. No estimates of type or quantity of this debris are available.

Northeast Region - New York Harbor Area

Debris Encountered by Category	Description
General Wood Items	The predominant material found floating in the New York Harbor area is wood. Accordingly, the following wood-item discussion contains the debris quantity information that is available concerning the area even though objects other than wood are found. The material that enters the water comes from one of the following sources: Decay of derelict vessels, deteriorating wharfs and piers, and deliberate and accidental dumping of material into the water. Figures F-2 and F-3 show typical examples of decaying piers and vessels in New York. An Army Corps of Engineers survey report concerning the floating debris situation in New York Harbor(1) estimates the quantity of debris found in the area and the contribution from each source.

(1) Department of the Army, New York District, Corps of Engineers, "New York Harbor Collection and Removal of Drift, Survey Report on Review of Project" (June 1968, Revised March 1969 and April 1971).

FIGURE F-2. DERELICT VESSELS IN KILL VAN KULL, WESTERN END OF SHOOTERS ISLAND, UNION COUNTY, NEW JERSEY[(1)]

(1) Army Corps of Engineers, New York District, op cit, Photo 5.

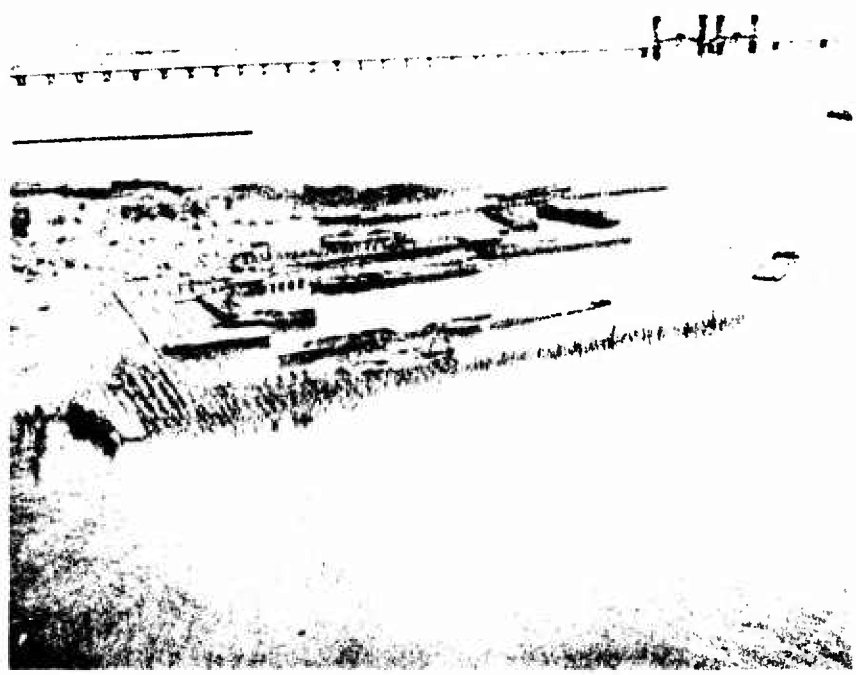


FIGURE F-3. PILING AND SUNKEN BARGES IN KILL VAN KULL, EASTERN END OF SHOOTERS ISLAND, RICHMOND COUNTY, NEW YORK AND HUDSON COUNTY, NEW JERSEY[1]

(1) Army Corps of Engineers, New York District, op cit, Photo 5.

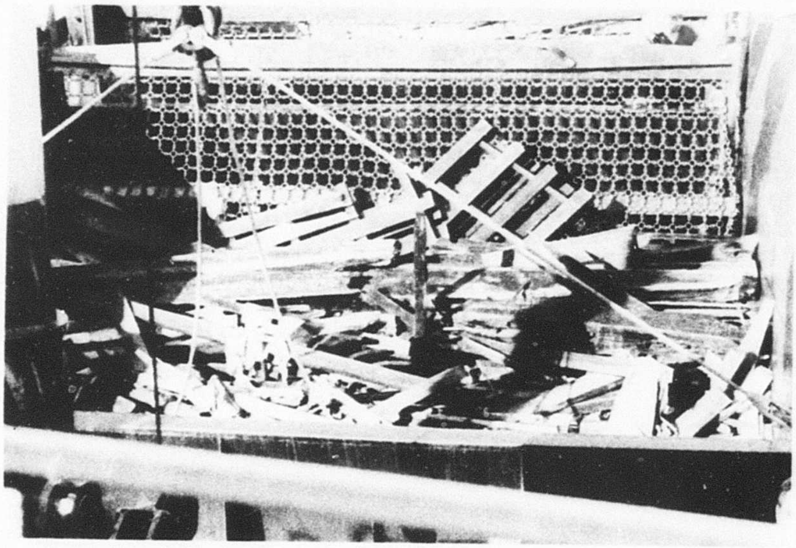
TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	The amount of loose, floating drift material existing in the Harbor in 1966 was estimated to be a nominal 1,320,000 cubic feet. The discussion of the debris sources in the area compared with the amount annually removed by the current Corps of Engineers cleanup operation indicated that in 1966 this figure was increasing yearly. No current estimates as to the total quantity of floating material are available. Of the sources discussed above, it was estimated that, in 1964, 113,000 cubic feet per year of material were entering the Harbor from derelict vessels and shore structures; 97,000 cubic feet per year from the drift that has collected on the shore; and 279,000 cubic feet per year from dumping directly in the water(1). It is noted that, of the above figures, the direct dumping total has probably decreased considerably due to the advent of cargo containerization. Much of the previous deliberate dumping was due to overboard disposal of dunnage during cargo handling, which no longer is the practice. Some material continues to enter the Harbor, however, due to shoreline construction and demolition activities and due to illegal domestic dumping. The nominal 1,320,000-cubic-foot figure could be expected to increase during and after severe storms or high water. The quantity of loose material on the shoreline was estimated in Reference 1 to be 1,300,000 cubic feet in 1964. The normal entry rates of material from the shore into the water was estimated as 5 percent of this figure

(1) New York District, Corps of Engineers, op cit.

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	for material above the mean-high-water line and 10 percent for material normally below the mean-high-water line, respectively. In a severe storm these rates could greatly increase. If the above- and below-mean-high-water input rates were to increase in a hurricane to 25 and 50 percent, respectively, the quantity of floating debris on the water immediately after a storm would be increased by 390,000 cubic feet (without regarding sudden increases due to the effect of severe wind action on derelict structures and vessels). This would increase the total for all floating material on the water to 1,710,000 cubic feet. Concentrations of debris in New York Harbor occur in slips, underneath docks, and in other locations where the wind tends to drive debris against a natural collector. Shifts in wind can bring a great deal of debris out of these collector areas and distribute the material over the local water surface. Other line concentrations occur in tidal rip areas or other places where currents converge with lines of material floating on the surface. Debris size in New York Harbor can vary from small to large with just about any type of manufactured wood item being found at one time or another. Normally, however, most of the material found (by weight) is large wood items such as timbers, telephone poles, pieces of shoring, etc. The commonly found small and medium wood items are dimension lumber. Figure F-4 shows typical



1101-73/F-4

FIGURE F-4. TYPICAL WOOD ITEMS RECOVERED IN NEW YORK OFF THE WATER BY THE CORPS

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	wood items picked up off the water by the Corps. Typical dockside debris and loose shoreline debris are shown in Figures F-5 and F-6, respectively. Estimates of the quantity of wood that could be expected in spills are difficult because of the local nature of the debris concentrations in New York. In some areas, even with the vast quantity of debris found in New York, the debris situation could be relatively minimal. An example of this type of situation is the USNS Towle spill of July 14, 1971. The quantity of debris recovered with the oil was minor. In future spills in other areas, especially large spills, much more debris could become involved.
Non-Rigid Shapes	Dead birds, dead rats and mice, and shoes are small shapes commonly floating in New York Harbor in fairly large quantities. Most of these items are found near the concentrations of population in the area.
Rigid Shapes	Small items found in this category include cigarette filters, toys, and plastic items of all types. Medium sized items found include metal boxes, pieces of boats, tires, luggage, plastic articles, and toys, with tires being the most numerous . Large items include boats, household furniture, refrigerators, and other domestic items which are dumped or otherwise find their way into the water. All items in this category are found near the population centers of the area.

FIGURE F-5. REMNANTS OF BARGE AND CATWALK IN NEWARK BAY, BAYONNE, HUDSON COUNTY, NEW JERSEY[1]

(1) Army Corps of Engineers, New York District, op cit, Photo 7.

FIGURE F-6. LOOSE DEBRIS ALONG SHORELINE OF NEWARK BAY, BAYONNE, HUDSON COUNTY, NEW JERSEY[1]

(1) Army Corps of Engineers, New York District, op cit, Photo 7.

TABLE F. (Continued)

Debris Encountered by Category	Description
Flexible Sheets	Canvas, articles of clothing, pieces of leather, pieces of rubber, paper, towels, prophylactics, plastic bags, rubber thongs, sheet plastic, rags, sheets, and other items are found, one item at a time, in many areas of the Harbor.
Rigid Sheets	Pieces of plastic, plywood, hatch covers, fences, pieces of scaffolding, and pallets are found in the Harbor. Plywood sheets and pieces of scaffolding are common in areas of shorefront construction.
Amorphous Material	Grease, wax, and other floatables from discharged sewage are found in many parts of the Harbor. No exact concentrations of material of this type are available, but an estimated 25 percent of the approximately 1.5 billion gallons per day of sewage from New York flowed into the Harbor untreated[1].
Filamentous Pieces	Some rope, fishing line, and nets are found floating in New York Harbor. The quantity of this material, relative to other contaminants, is small.

(1) Environmental Protection Agency, "Water Pollution Control Program", press release, New York City (undated).

TABLE F. (Continued)

Debris Encountered by Category	Description
Special Cases	Baseballs, basketballs, light bulbs, LNG bottles, oil drums, tennis balls, plastic bottles, milk cartons, paper cups, and soap cartons are all found in certain locations near population centers in New York Harbor. These items are usually found several at a time in any one location.
	Northeast Region - New York Offshore
General	Items floating in the open ocean offshore of New York, such as rotting garbage, have been reported[(1)]. This material apparently occurs over the ocean dumping site for New York's solid waste. No specific type or quantity information about this material is available.
	Northeast Region - Ports of Philadelphia Area
General Wood Items	The Ports of Philadelphia area includes the cities of Philadelphia, Chester, Trenton, Camden, and Wilmington, located on the Delaware River. The Schuylkill River also joins the Delaware at Philadelphia.

(1) Jones, Robert A., "N. Y. Horror: Sea of Sludge Lurks Offshore", Los Angeles Times (January 8, 1974).

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	General wood items found in the area include both natural wood debris--such as trees and tree limbs from the watersheds--and large lumber pieces from decaying docks and abandoned vessels. The natural wood debris is mainly present during spring and fall floods. Debris from the derelict structures and vessels is generally present all year round, with greatest concentrations occurring after high winds and waters. Much of the wood contributed by the decaying vessels and wharfs in Philadelphia comes from the Pettys Island area where several large wrecks and an estimated 12 decaying piers are located[1]. Types of debris from the vessels and wharfs include timbers, boards, pilings, etc. The quantity of wood found in the Ports area is less than that located in other Northeast/New England ports because of the constant net outward current carrying material downriver. Although subject to tidal current shifts, the River will still ultimately transport material out of the Ports area. An exception to this limited-quantity debris situation is when severe storms, such as hurricanes, occur. In the 1970 Schuylkill River oil spill after Hurricane Agnes, an estimated 700,000 cubic feet of material (mostly wood) was recovered. (However, an estimated 80 to 90 percent of this material was

(1) Delaware River Port Authority, "Keep the Delaware Shipshape".

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	recovered from riverbanks and not from the River itself, and this estimate includes a quantity of debris that had accumulated over a several-year period.) The Delaware River has had a similar debris situation when severe flooding occurs. The large pieces of debris material normally found in the River are usually encountered one item at a time. Pockets of debris do not occur as frequently as in other Northeast locations.
Rigid Shapes	Some isolated boxes, toys, crates, boats, and household furniture are found. Automobile tires are also found in certain locations.
Flexible Sheets	Plastic sheet material is found here and there in the Ports area. Clothing, towels, paper, etc., are found less frequently. Leaves are found in quiet waters in great quantity and concentration during the fall season.
Filamentous Pieces	Grass is found, especially in the fall, on the rivers of the area. Patches on the surface are common in quiet waters.
Special Cases	Isolated steel drums and tanks are commonly found on the River. These containers sometimes present a problem due

TABLE F. (Continued)

Debris Encountered by Category	Description
Special Cases (Continued)	to the hazardous material they contain. Some pressurized containers are also found.
	Northeast Region - Delaware Bay Area
General	Little information on the type and quantity of debris in Delaware Bay was obtained. Some wood is probably encountered one piece at a time near the Delaware River/Wilmington area, but most of what wood is present in the river is driven ashore as it enters the Bay. Dead marsh grass can present a debris problem in the fall. Also, a spring or summer spill could occur in a grassy area thereby causing a debris problem. In terms of the amount of material to be handled, marine growth will be the greatest debris problem with a spill in this area.
	Northeast Region - Baltimore Harbor Area
General Wood Items	Baltimore Harbor has a floating-wood type and quantity situation similar to that which is found in New York and Boston Harbors. As with other Northeast ports, all of the driftwood in the Harbor comes from derelict vessels, dilapidated wharfs, or deliberate dumping. The

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	Corps of Engineers, in 1970[1], estimated that there were 266 wrecks and 30 dilapidated structures which were debris sources in the Harbor. Records from the Maryland Port Administration and the Corps of Engineers[2] (both organizations collect debris in the Harbor) indicate that approximately 100,000 cubic feet of material was recovered from the Harbor in 1972. No estimates of the amount of wood present on the water at any one time are available. However, as the sources of debris in Baltimore are similar to those in New York, the debris concentrations in Baltimore Harbor can also be expected to be similar to those previously estimated for New York.
	Winds, storms, and tides have large effects on debris quantity, since there are no major rivers entering the

(1) Committee on Public Works, House of Representatives, 91st Congress, 2nd Session (91-51), "Report of the Chief of Engineers to the Secretary of the Army on A Study of the Need for and Disposal of Drift and Other Debris, Including Abandoned Vessels, From Public Harbors and Associated Channels Under the Jurisdiction of the Department of the Army" (December 1970).

(2) Notes obtained from the Maryland Port Administration and the Corps of Engineers, Baltimore Regional Office.

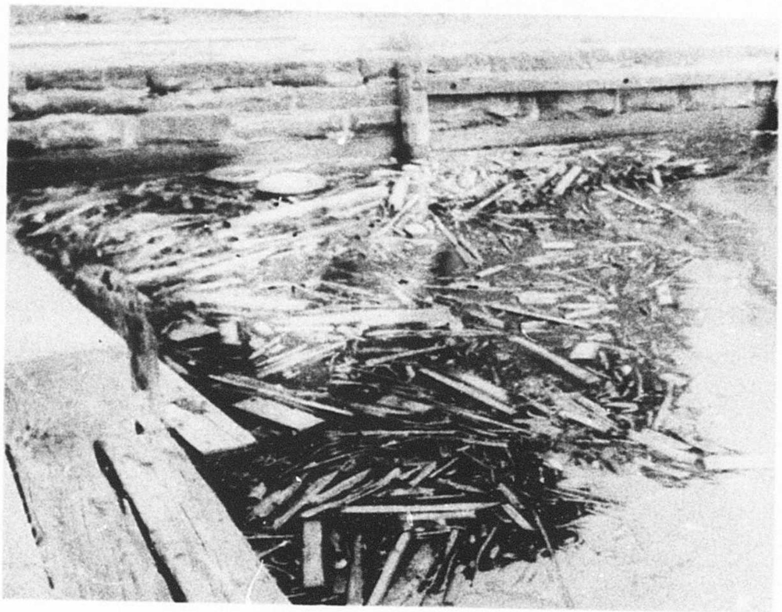


FIGURE F-7. TYPICAL DEBRIS CONCENTRATION IN BALTIMORE HARBOR IN THE CORNER OF A SLIP(1)

(1) Photo courtesy of Maryland Port Administration, Baltimore, Maryland.

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	Baltimore Harbor area. The amount of floating material on the water will increase with flood tides or strong winds blowing on an unusual heading. The lack of tidal flushing also contributes to the quantity found after a storm.
Other Types	Other debris types and concentrations are also similar to those found in New York Harbor.
	Northeast Region - Washington, D.C. Area
General Wood Items	Most of the debris material found in the Potomac and Anacostia Rivers at Washington is natural wood washed down during spring and fall floods from the watersheds of the two rivers. Trees, tree trunks, branches, limbs, etc., are the main items. No information on the amount of debris on the water at any one time is available, although the reported yearly total of debris removed from the Potomac in 1972 was 140,000 cubic feet. As for wood in oil spills, during high water after storms (especially severe storms such as hurricanes) pieces of wooden debris could be expected to be floating regularly in the River. Calm backwater areas, such as coves and eddies, could be expected to contain pockets of debris.

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	During normal water periods in summer, fall, and winter, only occasional pieces of wooden debris would be encountered.
Other Debris Types	Data on other debris types and quantities introduced into the Rivers is not available. Some municipal debris could be expected from the concentrations of population along the shore. The magnitude of this problem, however, would be less than in other metropolitan areas of the East due to the large amount of park land which lines the Washington shoreline. Leaves could be expected in great quantities during the fall.
	Northeast Region - Chesapeake Bay Area
General Wood Items	Wood items are found in the Chesapeake Bay area. Isolated pieces are encountered in the open waters of the Bay. In the estuaries and tidewater areas, more concentrated pockets of wood may be found during parts of the year. Types of wood include trees, tree limbs, planks, boards, timbers, and occasional pilings. The sources of wood in the Bay are the rivers which enter it and the abandoned boats and derelict structures along the shoreline. The rivers introduce most of their wood

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	into the estuaries during floods (such as occur during and after hurricanes). Most of the wood in the estuaries is held in these zones due to tidal action combined with the wind driving the material ashore. Some derelict structures and boats are located around the shoreline of the Bay (an estimated 1,000 boats line the Maryland shore[1]). The effect of these wrecks and derelict structures on local debris concentrations is limited, however, due to the great water area through which they are dispersed. Debris encountered in an oil spill would probably be limited to an occasional piece of wood here and there, with the possible exception of river estuaries around the Bay during a flood.
Filamentous Pieces	Much marine growth occurs in the area, especially in the northern end of the Bay. Typical plants include milfoil, water chestnut, and sea lettuce. From 1958 to 1965, an estimated 100,000 acres of milfoil grew in the upper Bay[2]. Although there is less milfoil now, it still

(.) Conversation with W. Shelly, Waterways Improvements Department, State of Maryland.

(2) Regional Planning Council, Baltimore, "Reconnaisance Study of the Chesapeake Bay" (September 1968).

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	grows in numerous locations. In a spill near shore, it could become involved with the spilled fluid in great quantity.
Other Types	Other types of debris could be expected here and there throughout the Bay stemming from the pleasure craft, naval craft, and cargo ships which navigate it. The quantity and concentration of this material is also fairly small.
	Atlantic Ocean Region
General	Data on man-made debris in the offshore areas of the Atlantic Ocean are very limited. Small plastic particles in the 0.25- to 0.5-centimeter range apparently are found in numerically large quantities(1, 2, 3) in the open water of the Atlantic. These particles are small and widely dispersed and would therefore not be expected to represent a problem to equipment during a spill recovery. What large items are found are expected to be similar in kind and quantity to the amounts reported in Reference 2. The reader is referred to the Oregon/Washington Coastal Area description for further details of items listed in that reference.

(1) Carpenter, E., et al, "Polystyrene Spherules in Coastal Waters", Science Magazine (November 17, 1972).

(2) Manheim, E. T., R. H. Meade, and G. C. Bond, "Suspended Matter in Surface Waters of the Atlantic Continental Margin from Cape Cod to the Florida Keys", Science Magazine (January 23, 1970).

(3) Carpenter, E. J. and K. L. Smith, Jr., "Plastics on the Sargasso Sea Surface", Science Magazine (March 1972).

TABLE F. (Continued)

Debris Encountered by Category	Description
	Mid-Atlantic Region - Norfolk/Hampton Roads Area
General Wood Items	Most material floating in the Hampton Roads area is wood drift from decaying structures. An Army Corps of Engineers report published in January, 1969, estimates that 58 derelict vessels and 140 dilapidated structures are located in the Hampton Roads area(1). The sources of debris in this area contain an estimated 3,400,000 cubic feet of material which could ultimately become floating debris. A debris-cleanup operation, run by the Corps, removed an average of approximately 72,000 cubic feet of debris per year during 1970-1972 from the Hampton Roads area. No data are available on the amount of debris on the water at any one time.
	Major channels outside the Hampton Roads Harbor area contain an estimated 20,000 cubic feet of floating wood drift(2). The same report estimates the sources of debris in these channels at 1.2 million cubic feet

(1) Department of the Army, Corps of Engineers, Norfolk District, "Collection and Removal of Drift in Norfolk District, Virginia" (January 1969).

(2) Ibid.

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	per channel. The total amount of floating drift located outside the Hampton Roads area in the Norfolk Corps District is estimated at 2 to 3 million cubic feet. Using these estimates, the amount of floating drift in the Norfolk area can be expected to resemble the 20,000 cubic feet that was estimated for the channel areas outside the Harbor. In a large oil spill, up to possibly 50 percent of this figure could be expected to be recovered with the spilled material. Factors such as high tides and storms increase the quantity of material on the water. The high tides float more material off the beaches, and normal or storm winds drive the material out into open water. Increased debris levels could be expected after a severe storm. Wooden debris in the Harbor area includes timbers, pilings, planks, boards, railroad ties, sticks, and camels. In the inland areas behind the Harbor, wooden debris is mostly natural wood -- trees, branches, and stumps that are washed down during floods from the river watershed.

TABLE F. (Continued)

Debris Encountered by Category	Description
Rigid Shapes	Tires, metal boxes, crates, pieces of boats, and pieces of cofferdams float in the Harbor area, especially after a flood.
Flexible Sheets	Great quantities of leaves are found both in Norfolk Harbor and in inland areas in the autumn. The leaves occur especially in pockets in backwater areas.
Rigid Sheets	Pieces of plywood, hatch covers, pieces of scaffolding, plywood panels, and pallets are found one item at a time in the Hampton Roads area.
Filamentous Pieces	Grass is found, especially in the fall, in great quantities in inland areas behind Hampton Roads. Weeds are also found on the water.
Special Cases	Paper milk cartons discarded from ships are reported in great quantity in the Hampton Roads area. They occur especially around the Navy areas of the Harbor.
	<u>Mid-Atlantic Region - Charleston, S.C.</u>
General	The geography and debris sources in Charleston Harbor closely resemble those of Savannah Harbor. For debris

TABLE F. (Continued)

Debris Encountered by Category	Description
General (Continued)	information the reader is referred to the discussion of Savannah Harbor which follows.
	<u>Mid-Atlantic Region - Savannah, Georgia, Harbor</u>
General Wood Items	Savannah Harbor is a port located on the Savannah River. The area is subject to tidal action from the Atlantic Ocean. The quantity of wood in the Harbor is small relative to other ports, such as in the Northeast. Some logs and large timbers are found one at a time, but most wooden material consists of branches and sticks washed down the river. Material is found on the Savannah River in appreciable quantity only after a storm or during spring flooding. Pockets of wood occur occasionally in still-water areas during these periods. Some pieces of cut wood, such as boards, are found year round in the water one item at a time. These pieces come from derelict structures and vessels located in the area.
Non-Rigid Shapes, Rigid Shapes, Flexible Sheets	Municipal trash is found on the rivers that lead into the Savannah Harbor area. Articles in these areas fall into three categories listed at the left. Little of this debris is found on open water, with most concentrated against banks or other fixed obstructions.

TABLE F. (Continued)

Debris Encountered by Category	Description
Amorphous Material	A great deal of pollen from marsh grass is found on the water in the spring. The individual pollen particles are very small and would not normally interfere with spill recovery, unless they were to be heavily concentrated in one location.
Filamentous Pieces	Great quantities of grass, marsh grass, and weeds are found in the Savannah River during the spring and fall--far more than wood during these seasons. Concentrated areas of marsh grass could be expected in an oil spill in the spring or fall.
Special Cases	A good many plastic cups are reported in the rivers that feed the Harbor area.
	Mid-Atlantic Region - Wilmington, N.C.
General	The geography and debris sources in Wilmington Harbor also closely resemble those of Savannah Harbor. For debris information, the reader is referred to the previous discussion.

TABLE F. (Continued)

Debris Encountered by Category	Description
	Florida Region - Jacksonville Area
General Wood Items	Occasional logs, branches, trees, boards, and timbers are found in the St. Johns River in Jacksonville. The Corps of Engineers(1) estimates there were 34 wrecks and 12 decaying structures in Jacksonville in 1970. This is the major source of man-made wooden debris in the area, although the quantity of this debris is small relative to other areas. Natural debris, such as logs, trees, and branches, comes out of the watershed area of the St. Johns River. The normal quantity of this debris is also relatively small, but it increases after a severe storm. Debris tends to gather in pockets in eddy areas of the River. Otherwise, it is found distributed on the water one item at a time.
Discrete Rigid Shapes	An example of unusual debris that can be found in an oil spill is provided by the spill from the Oriental Warrior. The Oriental Warrior had, as part of her cargo, thousands of plastic eyebrow pencil heads which floated off the ship when she sank. These pieces then mixed with the oil in great quantity and complicated the spill recovery.

(1) Committee on Public Works, op cit.

TABLE F. (Continued)

Debris Encountered by Category	Description
Flexible Sheets	Animal pelts were also carried as cargo on the Oriental Warrior. They too mixed in with the oil and caused a recovery problem. Water hyacinth grows in great quantity in estuaries and backwaters of Florida and Southern Georgia. It either floats on the water or grows off the banks. Any spill which occurs near the shore could be expected to involve large quantities of hyacinth.
Florida Region - Miami/Port Everglades Area	
General Wood Items	Very little wood is found in this area. What is found is scrap lumber from ship dunnage or from such activities as shorefront construction.
Non-Rigid Shapes	Palm fronds -- sometimes weighing several hundred pounds -- frequently float in this area. Their size and awkward shape has made them very difficult to handle in small spills. In some locations as many as 10 or 20 individual fronds can be found in one area.
Flexible Sheets	Water hyacinth occurs along the shorefront. Concentrations in a spill could be heavy if the spill were inshore in an area where hyacinth grows abundantly. Loose plants are blown by the wind into concentrations

TABLE F. (Continued)

Debris Encountered by Category	Description
Flexible Sheets (Continued)	in the corners of slips and coves. These concentrations would present a problem in recovering a spill.
Filamentous Pieces	Seaweed, turtle grass, and sargassum weed occur in this area in great quantity. Sargassum is especially prevalent in July and August. Turtle grass is found floating on the surface after shrimp harvesting and after October and November storms. The storms generate more material than the shrimping activities. All of these materials can be found covering the surface in certain local locations. At other times they are found floating a piece at a time in a given area.
	Saw grass occurs in heavy concentrations in the canals behind the Harbor areas. A great deal of grass would have to be removed in a large spill.
Special Cases	Coconuts are found fairly frequently in this area. Numerous coconuts can be concentrated in the ends of slips or in the lee of coves.
	Bottles and cans occur in fairly large concentrations in the area. Their source is the commercial shipping and pleasure-boat activity in the area. They are generally found on the open water one at a time.

TABLE F. (Continued)

Debris Encountered by Category	Description
Other Categories	General debris, such as plastic bags, paper cups, and other food- and beverage-associated waste from shipboard and municipal activities are found in certain local areas.
	Florida Region - Tampa Bay Area
General Wood Items	Some natural and man-made wood floats one item at a time in Tampa Bay. The quantity of this wood is small compared to ports in the Northeast or Northwest regions.
Flexible Sheets	Lily pads and hyacinth are found in large quantity in the Tampa Bay area. They could be expected to present a major problem in an oil spill. On some of the rivers entering the Bay, they completely cover the water surface.
Filamentous Pieces	Some seaweed is found in Tampa Bay. In general, the concentration of seaweed is much less than that of hyacinth or lily pads.
	Gulf Coast Region - Mobile Bay
General Wood Items	Wood items in Mobile Bay come from two sources: (1) shipping activities around Mobile, and (2) trees,

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	parts of trees, and some pieces of structures and timbers that are discharged from the Alabama and Tombigbee Rivers during a flood. The quantity of wood from these sources is moderate relative to other areas of the United States. The Mobile Harbor area collects much of the flood and cargo waste material that enters the Bay in slips, underneath wharfs, and in other collectors. In a recent spill of 100,000 gallons of oil, an estimated 10 cubic yards of wood were recovered from the slip in which the spill took place. This is apparently as much wood as could be expected in the Harbor area in a spill situation. In areas of the Bay away from the Mobile Harbor area, less wood would be found. Wood used to secure cargo (4 x 4-inch pieces, etc.) is sometimes discharged 8 or 10 pieces at a time into the Bay before ships dock at Mobile. This material could be found one piece at a time during an open-area spill in the Bay. Miscellaneous small debris in the Bay tends to flow toward the Dauphin Island area, where it is deposited on the beach. Tidal effects are minimal due to very small tides, so whatever material is driven ashore by the winds will probably remain there. However, winds out of the north

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	or severe storms will sometimes drive material out into the Bay. This material would be encountered one piece at a time, with total quantities being less than those found in Mobile Harbor.
Filamentous Pieces	Some sea grass grows in the Bay. It would present a minor problem in an oil spill.
Other Categories	Small amounts of municipal debris are occasionally found in the Bay.
	<u>Gulf Coast Region - Mississippi River Area</u>
General Wood Items	Most of the material floating in the Mississippi River near the Gulf of Mexico is wood. Typical items include trees, logs, dimension lumber (boards), sticks, and branches. Out in the current, wood is generally found one item at a time with some patches of floating wood occurring here and there. Concentrations of wooden material can occur in eddies and underneath natural debris traps, such as wharfs and coves. The greatest quantity of wood comes down the River in the December or May and June high-water periods. During these periods, the large quantities of material that are

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	normally trapped behind the rows of trees above normal water level are floated by the high water. In a spill during high-water periods, such as the Baton Rouge spill of March 25, 1973, some of the spilled material will mix in with the floating debris trapped behind the trees. This can create a severe debris situation in which a great quantity of debris is mixed with the spilled fluid. In the Baton Rouge spill (in which approximately 860,000 gallons of spilled fluid were recovered) an estimated 18,400 cubic feet of wood was recovered in a month[(1)]. The debris present in a typical Mississippi River spill is shown in Figure F-8. The major contributor to the wooden debris in the Mississippi, by weight, is trees. They range up to 2 to 3 feet in diameter, with 1 foot being typical. Other smaller material is also very common. Typical small and medium wooden debris found on the Mississippi is shown in Figure F-9.
Non-Rigid Shapes	Dead animals (large and small) are sometimes found floating in the River one at a time during a flood.

(1) Ray, LTJG K. L., "On-Scene Coordinator's Report", United States Coast Guard, New Orleans, LA (September 24, 1973).

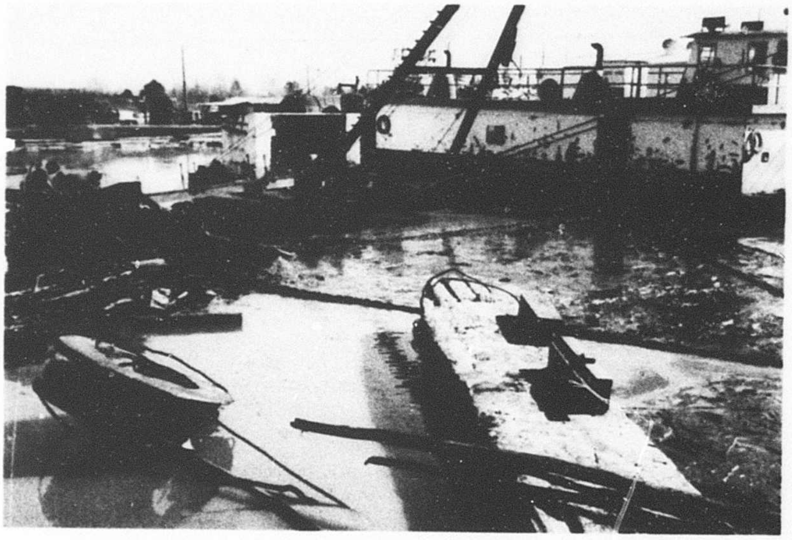


FIGURE F-8. SMALL WOODEN DEBRIS IN MISSISSIPPI RIVER OIL SPILL(1)

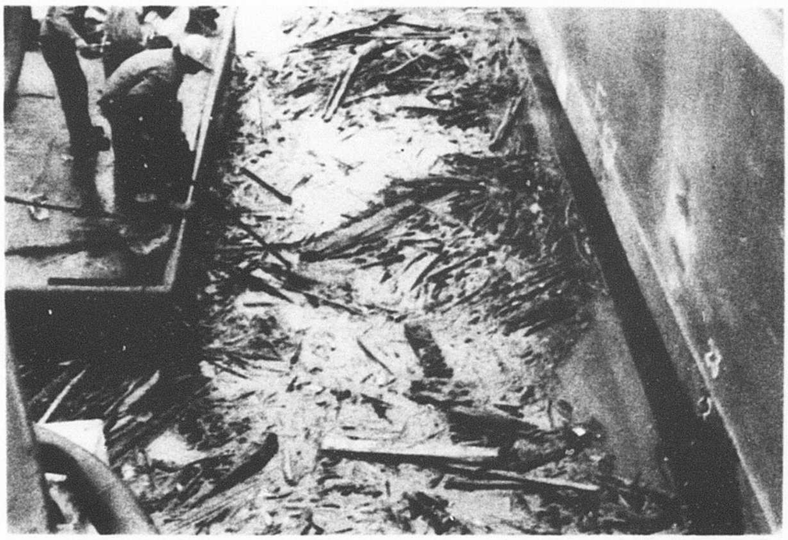


FIGURE F-9. SMALL WOODEN DEBRIS IN MISSISSIPPI RIVER SOYBEAN OIL SPILL(2)

(1) (2) Photos courtesy of Oil Mop, Inc., Belle Chasse, Louisiana.

TABLE F. (Continued)

Debris Encountered by Category	Description
Rigid Shapes	Boxes, crates, front porches, houses, and furniture float down the Mississippi during floods. The larger material is generally found one item at a time.
Filamentous Pieces	Lengths of rope are commonly found floating in the River.
Special Cases	Oil drums are a common piece of debris, especially around wharfs. At least one or two oil drums could be expected in the River during a large spill. It is also noted that some drums recovered contain hazardous substances and must be handled carefully.
Other Categories	Other kinds of municipal debris are found in the River near populated areas, such as Baton Rouge and New Orleans. The quantity of this miscellaneous debris is far less than the quantity of wood.
Gulf Coast Region - Mississippi Delta/Louisiana Coast Area	
Flexible Sheets and Filamentous Pieces	Reed grass, hyacinth, and lily pads grow in great numbers in the Louisiana Coastal and Mississippi Delta areas. This material could become involved in a spill if the spill were driven into these vegetated areas or if

TABLE F. (Continued)

Debris Encountered by Category	Description
Flexible Sheets and Filamentous Pieces (Continued)	floating plants were driven into the spill. (During some periods of the year, floating lily pads are driven into the immediate offshore area by offshore winds.) The quantity of this plant material would be far greater than any other type of debris in the area. A typical reed-grass situation with moderate quantities is shown in Figure F-10.
Non-Rigid Shapes	Occasional fish kills occur in the area due to red tide. These dead fish could be involved in a spill.
	Gulf Coast Region - Port Arthur/Galveston/Corpus Christi Harbor Areas
General	Only occasional debris is found floating in these areas. Much less man-made and natural material is found here than in other areas of the United States. This is apparently due to the general lack of vegetation on the watershed areas which drain into these ports, and to the general use of concrete shorefront structures which eliminates decay of wooden structures into the water. Rainfall in these areas is also light, causing a minimum of storm runoff and erosion. What debris is found usually occurs after a storm and consists mainly of occasional pieces of wood, such as tree

FIGURE F-10. REED GRASS FOUND FLOATING IN THE LOUISIANA COASTAL AREA(1)

(1) Photo courtesy of Oil Mop, Inc., Belle Chasse, Louisiana.

TABLE F. (Continued)

Debris Encountered by Category	Description
General (Continued)	stumps, trees, pile bracings, scrap lumber, planks, or pallets.
	Gulf Coast Region - Port of Houston Area
General Wood Items	The Port of Houston area has more floating debris than any other Gulf Coast port. A great deal of this material is wood. All types of man-made wooden items enter the water, including railroad ties, pilings, timbers, boards, planks, paddles, and telephone poles. Some small pieces of natural wood are also washed down from the bayous due to bank erosion. The Port of Houston operates a small debris-cleanup operation that removes a daily average of 270 cubic feet of drift material -- mostly large wooden objects floating in the navigation channel. Additional material not picked up by the cleanup operation is driven into bends of the channel and underneath docks by the wind. This material generally remains trapped in these locations, as there is normally no appreciable current in the channel. During a spill, the spilled fluid is also driven into the same locations, where the debris and spilled fluids mix. In a recent medium sized spill, the quantity of debris recovered was estimated as much more than the quantity of oil recovered. In any spill that is not immediately

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	contained, a great quantity of debris can be expected. Storms have a large effect on the quantity of debris in the Port. Much of the debris comes from dumping into bayous which feed the Port area. These bayous, normally dry, flood during storms; and the material that has been dumped is washed out into the Port. Far more debris is found in the area after a storm. Concentrations of debris can be expected during a spill. A typical spill which has been driven into a bend of the river that is covered with debris is shown in Figures F-11 and F-12. In a large spill, at least part of the water surface could be expected to be in a similar condition. Typical shoreline debris in the Port of Houston area is shown in Figure F-13.
Non-Rigid Shapes	Small dead animals are commonly found in the Port area. Some could be expected in a medium or large spill. Large dead animals, such as horses or cows, are regularly found in the area. One horse or cow might be encountered in a large spill.
Rigid Shapes	Toys, plastic items, boxes, furniture, luggage, plastic buckets, paint brushes, pens, toothbrushes, and occasional pianos, organs, and refrigerators are found in the Port. Some of the smaller items could be expected

FIGURE F-11. DEBRIS IN HOUSTON SHIP CHANNEL SPILL(1)

(1) Photo courtesy of United States Coast Guard, Captain of the Port, Port of Houston, Texas.

FIGURE F-12. CLOSEUP OF DEBRIS IN SPILL SHOWN IN FIGURE F-11(1)

(1) Photo courtesy of United States Coast Guard, Captain of the Port, Port of Houston, Texas.

1101-73/F-13

FIGURE F-13. TYPICAL SHORELINE DEBRIS IN THE PORT OF HOUSTON

TABLE F. (Continued)

Debris Encountered by Category	Description
Rigid Shapes (Continued)	in any spill, and the larger items could be expected in medium or large spills. Also, resin beads and rice lost during cargo handling are found floating on the water. The quantity of this material would depend on when the handling took place. In some cases of large spillage during handling, the material could cover the local water surface. A great many car tires are found in the Port. Hundreds (possibly thousands) of tires line the bank or float in the Port. Ten to 20 tires could be expected in any medium sized spill.
Flexible Sheets	Clothing, canvas, plastic sheets and bags, pieces of rubber, towels, and other sheet material are commonly found in the Port. Some items, piece by piece, could be expected in a spill.
Rigid Sheets	Pieces of sheet plastic, sheet plywood, and pallets are commonly found in the area. Some would be found in any spill in the area.
Filamentous Pieces	Brush from the banks of the bayous is found in the Port during certain times of the year. The quantity of this material can be appreciable, with the entire water areas of some bends being covered with brush.

TABLE F. (Continued)

Debris Encountered by Category	Description
Special Cases	Baseballs, basketballs, tennis balls, ping-pong balls, and other balls are often found. Lacquer cans, Clorox bottles, milk cartons, soap cartons, and paper cups are also common. A large quantity of these articles could be expected in any spill.
	Gulf of Mexico Region
General	No detailed information is available on the type and quantity of floating debris in the Gulf of Mexico. Discussions with Coast Guard personnel in the area indicate that some wood is discharged from the Mississippi and that other wood enters the water from ships dumping it overboard before entering the navigation channel to New Orleans. Apparently, little wood is found on the surface in any one area, and what is found consists of separate pieces distributed over large areas. In the Chevron offshore platform fire and oil spill, which occurred near the mouth of the Mississippi River, no debris problems were reported[1]. Also, aerial photographs of the oil slicks produced by the incident show no large debris in the area[2].

(1) Alpine Geophysical Associates, Inc., "Oil Pollution Incident, Platform Charlie, Main Pass Block 41 Field, Louisiana", Norwood, New Jersey 07648 (May 1971).

(2) Catoe, C. E., "Results of Overflights of Chevron Oil Spill in Gulf of Mexico", Office of Research and Development, U. S. Coast Guard Headquarters (May 19, 1970).

TABLE F. (Continued)

Debris Encountered by Category	Description
	California Region - San Diego Harbor Area
General Wood Items	San Diego Harbor is an enclosed bay with very little natural drainage into the area. What watershed does drain into the bay is semi-arid with limited natural foliage. Natural wood entering the Bay from runoff is limited to some branches and twigs. Some cut lumber, fender piles, and miscellaneous wood dunnage enters the Harbor waters due to shipping activity. The quantity of this material is limited, however, by enforcement of regulations concerning dumping and concerning shorefront construction. The lack of decaying shorefront structures eliminates debris input from that source. Little wood could be expected in an oil spill -- possibly an occasional piece in open water and some small pockets of several pieces in calm waters.
Other Categories	A small amount of municipal trash and refuse from boating activities (such as car tires and plastic bottles) is found in certain locations in the Bay. In a spill some trash items could be expected, but not in great quantities. Palm fronds are found in the water in certain parts of the Bay. Since they can weigh several hundred pounds, their handling in a spill would be extremely difficult.

TABLE F. (Continued)

Debris Encountered by Category	Description
Other Categories (Continued)	On occasion, Perlite discharged from kelp-processing operations has been found floating in the Bay. The particles of Perlite have occurred locally in fairly large quantity.
California Region - Los Angeles/Long Beach Harbor Area	
General Wood Items	Fairly small quantities of manufactured wood are found in the Los Angeles/Long Beach Harbor area under normal circumstances (relative to ports in the Northeast and Northwest). Items found include pilings, railroad ties, telephone poles, timbers, and boards. Most wood items are medium sized, although a considerable number are large. After especially severe storms, large amounts of material can enter the Harbor area through the normally dry Los Angeles River and the Dominguez Channel. Most of the wooden material that enters the Harbor during these periods is man-made, although a considerable amount of natural wood, such as branches, may come down the Los Angeles River Channel. Under normal conditions, a spill would probably encounter a small quantity of wood found one piece at a time in open water, and some small concentrations of wood under

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	docks and in slips. After a severe storm, the quantity of wood might double or triple, but it would still be fairly small.
Non-Rigid Shapes	Occasional items such as dead seals, jellyfish, and dead birds are found in the harbor area.
Rigid Shapes	Cigarette filters, toys, plastic items, tires, crates, and floats are found here and there one item at a time. Refrigerators, pianos, and other items of furniture are found occasionally.
Flexible Sheets	Paper, plastic sheets, plastic "six-pack" holders, cloth, pieces of rubber, sheets, and towels are found one item at a time, especially at the ends of slips.
Rigid Sheets	Sheet plywood, pallets, and pieces of scaffolding are occasionally found one item at a time.
Filamentous Pieces	Large quantities of tule grass are found floating in some parts of Long Beach Harbor after the first severe rainstorm of the season. Winds and currents wash it down the Los Angeles River Channel and spread it out throughout the east end of the Harbor. Figure F-14 shows this area of the Harbor after the first rain of fall, 1973. A close-up of typical material in that concentration is shown in Figure F-15.

1101-73/F-14

FIGURE F-14. REED-TYPE MATERIAL IN LONG BEACH HARBOR

1101-73/F-15

FIGURE F-15. CLOSEUP OF MATERIAL SHOWN IN FIGURE F-14

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	Hemp, cellulose fibers, and grain are found on the water in areas where these materials are transferred from ship to shore. Only small amounts are found -- and only when these items are being handled. Occasional pieces of rope and fishing line are also found.
Special Cases	Baseballs, basketballs, tennis balls, ping-pong balls, pieces of fruit, milk cartons, and paper cups are found here and there in the dockside area of the Harbor. Some of these items could be expected in a spill in these areas. Occasional floating steel drums and steel bottles are also found.
	<u>California Region - Southern California Offshore</u>
Filamentous Pieces	Kelp beds abound all along the Southern California coastal shelf. Some patches of kelp are also found drifting in open, deeper water. The beds near shore, which are quite dense, proved such a hindrance to oil-recovery operations in the Santa Barbara spill of 1969 that oil which entered the beds could not be collected.

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	In any medium or large spill near shore, large quantities of kelp could be expected.
Other	A few items such as pieces of wood or plastic are encountered on the open water (relative to the quantities found in port areas). In small spills, no significant amount of this debris would be expected.
	California Region - San Francisco Bay Area
General Wood Items	Almost all of the material floating in the San Francisco Bay area is wood. Most consists of fabricated items; little natural wood occurs. Concentrations of wood are normally found in two areas -- the dockside and immediate offshore areas around San Francisco, Oakland, Alameda, and Richmond; and the open-water areas where pronounced tide rips occur near Angel Island. The material in the dockside areas usually floats along the shoreline or is stranded on the beach above the normal high-water mark. The material in the rips is distributed in a line along the rip, as shown in Figure F-16. The quantity of debris found in either location depends greatly on the magnitude of the tides, the weather, and wind conditions. The heaviest quantities of debris

1101-73/F-16

FIGURE F-16. DEBRIS MATERIAL IN TIDE RIP IN SAN FRANCISCO BAY

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	occurs during flood tides after a storm. The material that is normally stranded above the high-water mark floats off and is transported by winds and currents into open water. The situation near Angel Island is especially bad during these periods. The Corps of Engineers has collected as much as 1,700 cubic feet of wood from these rips in 1 hour during an extremely bad period[(1)]. On several occasions, the two Corps boats have collected daily totals of 11,500 cubic feet of debris. Less wood is found in the Bay area during periods of normal tides and winds, but it is always present. In any spill in the open waters near Angel Island or in the dock areas, wooden debris can be expected at all times. Two examples of spills during flood tides are the Chevron tanker collision spill in the Golden Gate on January 18, 1971, and the Oakland Estuary oil spill of January 19, 1973. Both spill-cleanup operations were hampered by large quantities of debris mixed in with the oil. No estimates of the amount of debris recovered in the Chevron spill are available, but discussions with the individuals involved indicate that the amount of debris recovered was within the same order of magnitude as the amount of oil. Since 20,000 barrels (approximately

(1) Meeting between W. Angeloni of the Army Corps of Engineers, Sausalito, California, and Battelle staff (January 17, 1974).

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	110,000 cubic feet) of bunker fuel were spilled, the amount of debris recovered is estimated at 5,000 to 50,000 cubic feet. This debris consisted mainly of wood. Reference 1 estimates the amount of debris recovered in the Oakland Estuary spill at 37,800 cubic feet. A typical debris situation in the Oakland Estuary spill is shown in Figure F-17. Wooden debris in the San Francisco Bay area includes such items as timbers, railroad poles, boards, sticks, camels, pilings, and planks. In the Angel Island area, the majority of material, by weight, is large, with a great deal of timber. In the Oakland/San Francisco/Alameda areas, more medium and small-sized wood is found. Some natural trees and branches are found in all parts of the Bay.
Non-Rigid Shapes	Dead seals and occasional small dead animals are found in the Bay area. These are encountered one item at a time, and more than one would not normally be expected in an oil spill. Life jackets and cardboard boxes are found more frequently.

(1) Clean Bay, Inc., "Cleaning Up the Oakland Estuary Spill, January 19-26, 1973", Concord, California (1973).

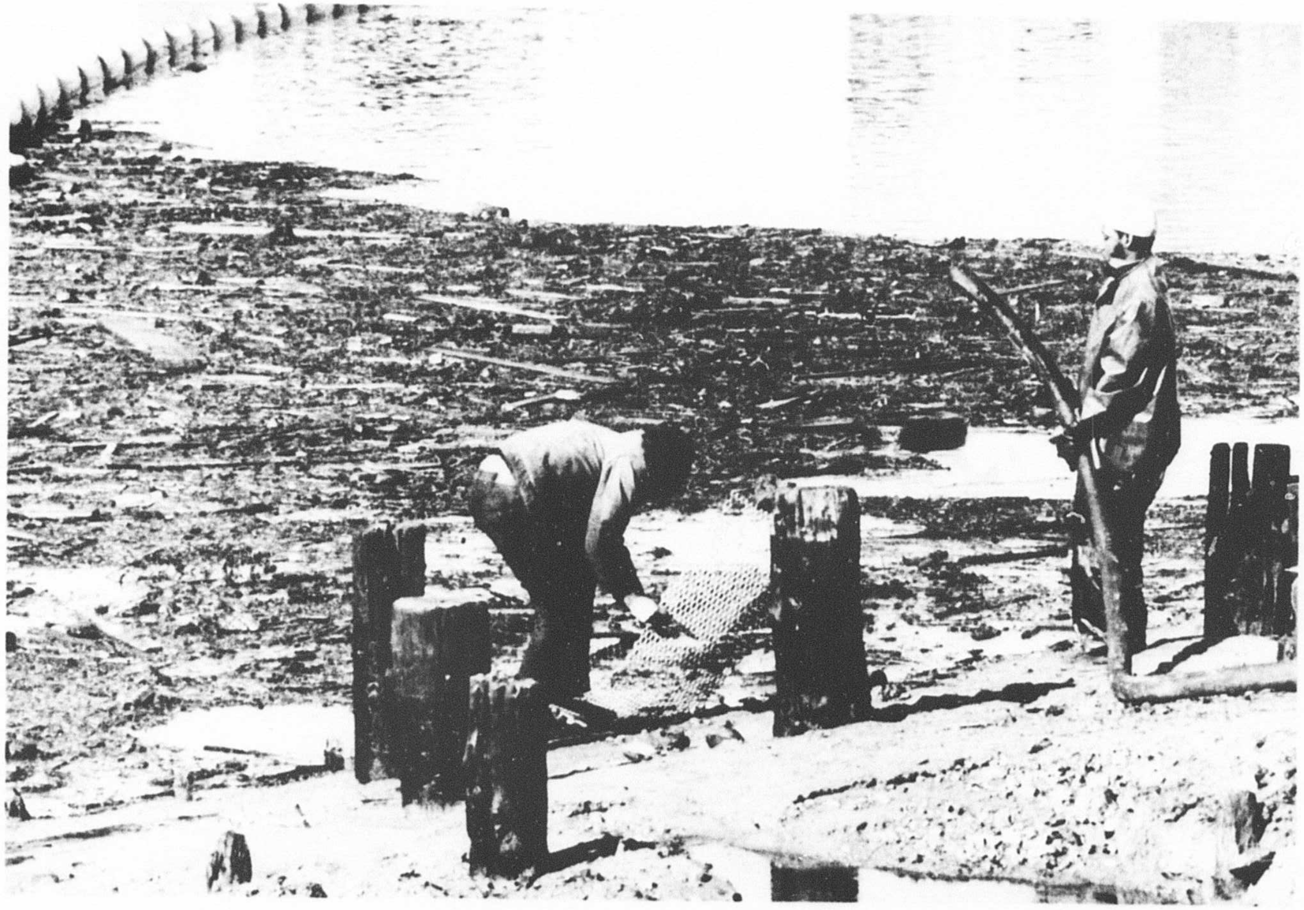


FIGURE F-17. CONCENTRATION OF DEBRIS ALONG SHORE OF OAKLAND-ALAMEDA ESTUARY[(1)]

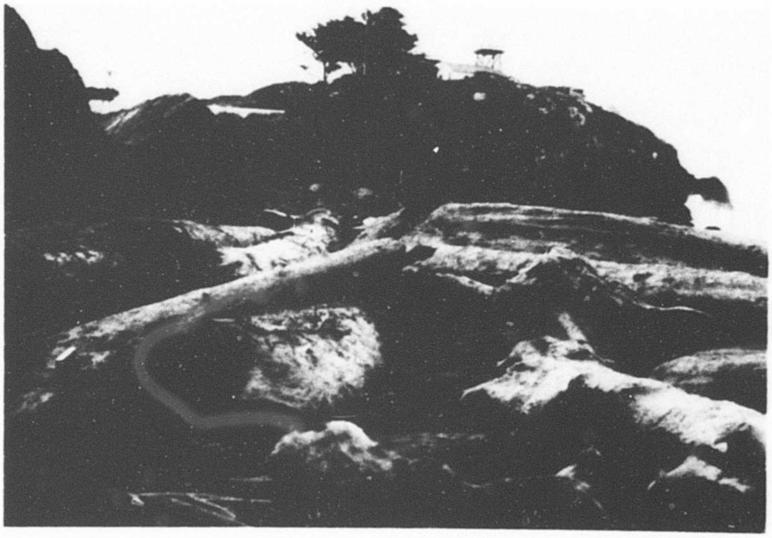
(1) Twelfth U. S. Coast Guard District, San Francisco, California, Official USCG Photo, File No. 012073 9.

TABLE F. (Continued)

Debris Encountered by Category	Description
Rigid Shapes	Floats, life preservers, pieces of furniture, crates, plastic buckets, toys, pieces of boats, and dinghies are found throughout the bay, one item at a time. Car tires occur frequently in all populated parts of the Bay.
Flexible Sheets	Plastic sheets are commonly found floating in the Bay, one piece at a time. Paper and canvas are also encountered occasionally.
Rigid Sheets	A great deal of plywood sheeting is found in the Bay, especially near shore. Pallets are also common.
Amorphous Material	Peat moss floats into the Bay from the Sacramento Delta area during parts of the year. Areas of water 20 feet across are sometimes covered with peat moss.
Filamentous Pieces	Tule grass floats in the Bay at all times. Heaviest concentrations occur during late fall, winter and spring. Large quantities can be expected in medium or large spills. Pieces of rope and hausers are also found one piece at a time.
Special Cases	Baseballs, tennis balls, oil drums, cans and bottles of all types, milk cartons, and paper cups are all found in the Bay. Some of these items can be expected in all spills near shore.

TABLE F. (Continued)

Debris Encountered by Category	Description
	California Region - Northern California Coastal Area
General	The debris situation in the Northern California coastal area is very similar to the Oregon/Washington coastal area. The same logging activities contribute most of the man-made debris. The reader is referred to that section for a discussion of debris type and quantity. Typical shoreline debris is shown in Figures F-18 and F-19.
	Northwest Region - Oregon/Washington Coastal Area
General Wood Items	Debris encountered along the Oregon/Washington coast consists mainly of wood articles from logging activities and natural wood produced by hillside erosion. The logging debris consists of slash left in the hills that is washed into the rivers during storms, and loose logs and bark chips that enter the water during log rafting. Log rafting along the coast is confined to the sheltered water, estuarine, and river areas along the coast. Deadheads (logs floating partially or entirely submerged), floating logs, and bark chips associated with rafting are far more prevalent in these sheltered areas than in the open water offshore. Normal concentrations of wooden



1101-73/F-18

FIGURE F-18. SHORELINE DEBRIS AT CRESCENT CITY, CALIFORNIA

1101-73/F-19

FIGURE F-19. SHORELINE DEBRIS AT KLAMATH, CALIFORNIA

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	debris would consist of occasional large logs (20 to 40 feet in length), with concentrations of wood chips, branches, and other light material occurring in tidal rips or in relatively calm backwater areas. After severe storms, the debris concentration in rivers and estuaries increases. Most of the material that comes out of the hills comes during these periods of heavy rainfall. Severe storms can also break up log rafts and cause material to come off of decaying structures. The latter problem is relatively minor in this area when compared to other areas of the country, for the coastal region is lightly populated. After a very severe storm, medium to large floating wooden items can be expected to occur regularly in the estuaries and rivers. Far less wood debris is found offshore than close to shore. Occasional large logs and deadheads are encountered in open water. The largest concentration of offshore debris will be encountered when flood tides are accompanied by offshore winds. Then the accumulated debris that is normally stranded on the beach will tend to come off and float out to sea. Typical concentrations of beach debris on the Washington Coast are shown in Figures F-20 and F-21.
Filamentous Pieces	In some of the coastal harbors, such as Grays Harbor and Coos Bay, pulp fibers and wood chips are found in the

1101-73/F-20

FIGURE F-20. BEACH DEBRIS AT KALALOCH, WASHINGTON

1101-73/F-21

FIGURE F-21. BEACH DEBRIS AT KALALOCH, WASHINGTON, CLOSEUP

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces (Continued)	water due to the activities around the local paper mills. These conditions are extremely local and would only occur in magnitudes sufficient to hamper a spill operation if a spillage or accidental discharge took place. Particles of pulp and wood chips are found normally, but are randomly spaced and few (relative to the larger wood pieces).
Rigid Shapes and Special Cases	Some articles other than wood are found in open waters of the Pacific Ocean. Their concentration is such that they would affect a spill operation very little. The reader is referred to the Pacific Ocean Region discussion for a further description of these items.
	Northwest Region - Lower Columbia River/Portland Area
General Wood Items	Debris in the Columbia River from Portland to the Pacific Ocean is primarily wood from logging activities upstream. Common items include stumps, limbs, branches, roots, and logs. After heavy flooding and, to a lesser extent, during nominal high-water periods, wood from structures, derelicts, and cargo-handling activities on both the Columbia and Willamette Rivers is also washed down into the Columbia. In addition, large trees are often washed down both the Columbia and the Willamette Rivers during

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	heavy floods. A derelict wharf, typical of the debris sources in the Port of Portland area, is shown in Figure F-22. Generally, most of the debris that comes down the Columbia or the Willamette Rivers is driven ashore by the wind before it reaches the Pacific Ocean. A large amount of material from the Willamette River is stranded locally at Portland underneath the docks. Much of this material is relatively large. In the Willamette River oil spill of September 6, 1973, approximately one-half of the debris recovered was too heavy to be handled by two men. Another problem during this spill involved the contamination of several log rafts with oil. The logs were removed from the water and are being held pending legal action to determine whether they should be salvaged or disposed of. The complicating factor in this case is the value of the logs. The loss involved in disposal of even one log raft is considerable. Contamination of log rafts with oil is a possibility in many spill situations which could occur in the Northwest. The quantity of wooden debris to be expected in a spill in this area varies greatly according to the time of year. After a severe storm, certain calm-water areas are partially or completely covered by wooden debris. Other areas, where currents are always present, constantly

1101-73/F-22

FIGURE F-22. DERELICT WHARF AREA IN PORT OF PORTLAND

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	receive pieces of wooden debris that are distributed in the River. During other periods, the total quantity of debris is less, with summer low-water periods having the smallest concentration of debris. During the summer, only random wooden pieces could be expected in these areas, one at a time.
Non-Rigid Shapes	Some life jackets, sleeping bags, and car tires are found in the River near Portland, especially after severe storms. The quantity of these items is several orders of magnitude less than wooden debris.
Rigid Shapes	Some articles such as float houses, chicken houses, pieces of piers, pieces of barges, derelict boats, and pieces of houses come down the River after severe storms. These items occur randomly and are found one at a time, most frequently near the populated Portland area.
Flexible Sheets, Rigid Sheets, and Special Cases	Some materials, such as clothing, paper, milk cartons, bottles, cans, rags, and pieces of sheet plastic are found near Portland during and after floods. This material mixes with wood debris underneath the docks and in eddies of the Rivers. The quantity of this material is estimated to be approximately one to two orders of magnitude less than wooden debris in an area.

TABLE F. (Continued)

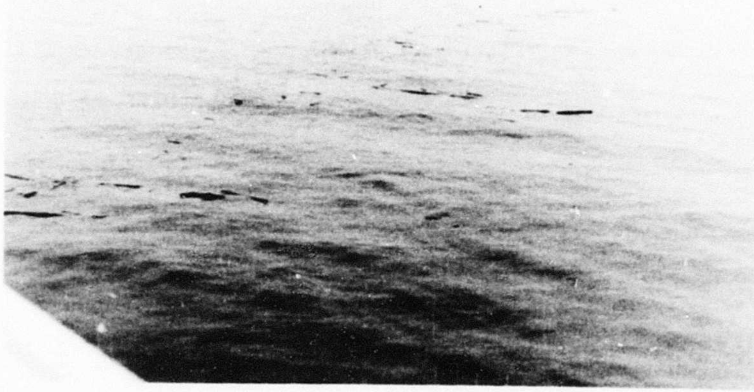
Debris Encountered by Category	Description
Filamentous Pieces	Pulp fiber from ship-loading activities is found in certain areas of the Port of Portland. The quantity varies depending on the frequency of ship-loading activities.
	Northwest Region - Straits of Juan De Fuca Area
General Wood Items	A great many small, medium, and large wood items are found in large quantities in this area -- the result of logging and natural erosion which causes trees to enter the local waterways. Trees entering the water due to erosion of a bank are shown in Figure F-23. Logging contributes wooden debris of all types--including logs from log rafts and bark chips that come off these rafts due to the logs rubbing together. Also included are branches, limbs, trunks, and other slash material left from logging activities in the hills that are washed down during storms. The trees that erode are initially intact, but weathering soon reduces them to separate branches, limbs, and trunks. The rivers in this region transport much eroded wooden material and support extensive log-rafting activities in the vicinity of the Straits. Wooden debris is more concentrated in the estuaries of the rivers than in the Straits due to these effects. In general, the debris load of new

1101-73/F-23

FIGURE F-23. TREES ERODING INTO THE STRAITS OF JUAN DE FUCA

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	material into the Straits from the adjacent countryside is greater during and after heavy winter rains. Greatest concentration of material occurs on the open waters of the Straits during winter flood tides when the prevailing winds shift from onshore to offshore. In this situation, material that has been driven onto the beach above the normal high-tide line will float away. This happens off Dungeness Spit when high winds out of the Northeast are accompanied by high tides. As Dungeness tends to collect material during the normal westerly winds (due to its location in the Straits), the effect of debris coming off in the situation described above can be severe. Typical concentrations of wood material trapped in the kelp lines and tidal rip lines of the Strait during December are shown in Figures F-24 and F-25, respectively. As can be seen, the debris gathers in distinct lines which run parallel to the shoreline. Spilled fluid could be expected to be driven into the same locations. Special situations occur in Victoria and Port Angeles Harbors. Victoria Harbor has typical quantities of shipping-port wooden debris on the water. Pieces of old docks, tops of pilings, and dunnage from ship cargo-handling activities are typical items found. Port



1101-73/F-24

FIGURE F-24. MATERIAL IN TIDAL LINES IN THE STRAITS OF JUAN DE FUCA

1101-73/F-25

FIGURE F-25. TYPICAL DEBRIS MATERIAL IN THE STRAITS OF JUAN DE FUCA

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	Angeles Harbor is a typical logging port. Bark chips and legs broken loose from log rafts are common there. Deadheads floating partially submerged in the Straits are common; they could damage oil recovery equipment. As of now, no oil-spill cleanups have taken place in the Straits.
Flexible Sheets	Visqueen plastic sheets (apparently blown off of deck cargo) have reportedly been found floating in the Straits These sheets occur randomly and are found floating one at a time. In a medium sized spill, perhaps one or two sheets could be anticipated.
Filamentous Pieces	Kelp grows in fairly large quantities along the Straits Kelp growing in place would hamper spill recovery if the spill were to float into it. Kelp torn loose from the bottom during a severe storm and floating in tidal areas could become mixed with a spill. Figure F-26 shows a typical kelp bed in the area.

1101-73/F-26

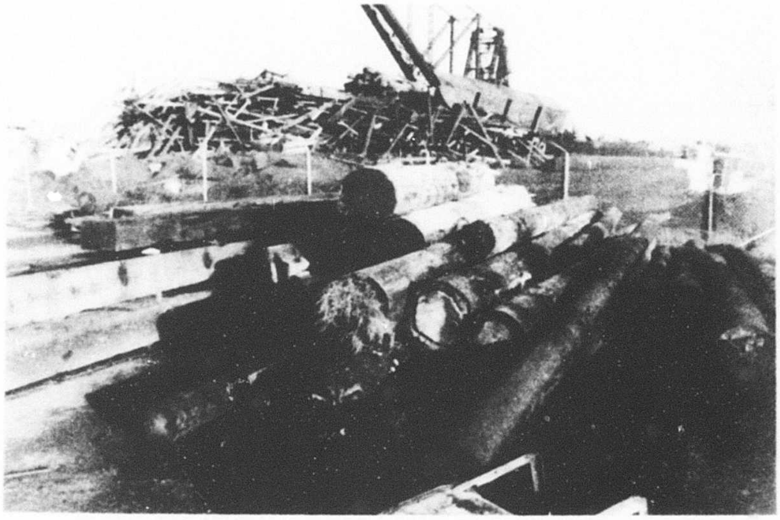
FIGURE F-26. TYPICAL KELP BED IN THE STRAITS OF JUAN DE FUCA

TABLE F. (Continued)

Debris Encountered by Category	Description
	Northwest Region - Puget Sound Area
General Wood Items	Floating wood items are found throughout the Puget Sound area. These items, along with kelp, constitute most of the debris found in the region. Log rafting and logging activities provide the major source for this material. Log rafting contributes both stray logs and bark caused by the logs' rubbing together. Deadheads present a special problem in the Sound due to their poor visibility. The bark that is produced by the rafting is found throughout the Sound area. Extensive log-storage areas that contribute raft debris are located in the Tacoma, Oakland Bay, Henderson Inlet, Budd Inlet, Everett, Port Townsend, Skagit Bay, Padilla Bay, and Bellingham Bay areas. Stumps, limbs, roots, and branches left from logging activities enter the Sound from surrounding areas during heavy rains. The material that enters Puget Sound is distributed by winds and tidal action. Many small wood items and some larger ones are found in tidal rips in the Sound. The quantity of material in the water varies somewhat from season to season, with the winter months having the heaviest concentrations and the summer months the lightest. However, the difference in concentration due to seasonal effects in the Sound is less than in the other areas of the Northwest.

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	This may be due to the fact that the losses from rafting are about the same all year round. Great quantities of debris can be distributed over the surface of the Sound when flood tides are accompanied by offshore winds. Debris on the beaches is floated off by the tides and driven into the Sound by the wind. This situation can occur anywhere in the Sound. Material recovered by the Corps of Engineers from Puget Sound is shown in Figures F-27 and F-28. Wooden pallets, oars, pieces of dimension lumber, telephone poles, railroad ties, pieces of scaffolding, and other wooden debris is found in various parts of the Sound. This material intermixes with the logging debris, only it occurs in much smaller concentrations.
Flexible Sheets	Visqueen plastic sheets are found floating singly throughout the Sound. These sheets vary from approximately 1 by 1 foot to 12 by 12 feet and larger. This material is blown or discarded off of ships or dock-storage areas where the material is used to protect cut lumber. Some canvas sheets are found, although not as many as the Visqueen type.



1101-73/F-27

FIGURE F-27. DEBRIS MATERIAL RECOVERED FROM PUGET SOUND

1101-73/F-28

FIGURE F-28. DEBRIS MATERIAL RECOVERED FROM PUGET SOUND

TABLE F. (Continued)

Debris Encountered by Category	Description
Filamentous Pieces	Kelp is common throughout the Sound in fairly large quantities. Spilled fluid can be expected to interact with kelp in most areas of the Sound. Rope and fishing line are also found periodically.
Special Cases	Some cans, bottles, milk cartons, metal tanks, and paper cups are found floating. Few of these items are found in the open water when compared with the quantity of wood.
Northwest Region - Seattle/Tacoma Metropolitan Area	
General Wood Items	The Puget Sound areas that front on the Seattle/Tacoma shoreline have, in addition to the types of debris present in the open waters of Puget Sound, small and medium sized wooden debris from docks, warehouses, and other municipal activities in the area. The quantity of wooden debris in this area of the Sound is estimated at only slightly more than what is found in the less populated areas. In sheltered areas, such as Elliot Bay or the Duwamish Waterway, considerably more debris is found than in the open Sound, due to the large amount of dockside activity and the proximity of municipal activities. The debris found in these areas tends to contain a high percentage of small material and cut lumber. Concentrations of debris occur

TABLE F. (Continued)

Debris Encountered by Category	Description
General Wood Items (Continued)	in the corners of slips, underneath piers, and in other confined areas of the harbor where the wind drives it. In these concentrated areas, it is estimated that as little as 20 square feet to as much as 500 square feet or more of the surface may be uniformly covered. In the open areas of Elliot Bay, the material could be expected to be distributed. Random logs and deadheads, such as those in Puget Sound, also occur in the harbor areas. Commencement Bay, in Tacoma, has a similar situation. Typical shoreline debris near Seattle is shown in Figure F-29. Typical debris in the corner of a slip is shown in Figure F-30. The amount of floating debris that would need to be picked up yearly to keep the Seattle area clear is reported as 390,000 cubic feet[(1)]. Of this figure, the amount of small debris, rubbish, and trash is estimated at 25 percent of the total, or approximately 97,500 cubic feet per year. Extrapolations from these figures yield an estimate of the amount of material that could be encountered in a large spill in the Seattle area. If one-quarter of the material listed above were assumed to be on the water at a given time (say, after a storm), and of that, one-quarter were found in with a large spill, the total floating material involved would be 25,000 cubic feet, approximately.

(1) Municipality of Metropolitan Seattle, "Floating Debris and Litter Removal Study" (March 1972).

1101-73/F-29

FIGURE F-29. SHORELINE DEBRIS AT WEST POINT AREA, SEATTLE

1101-73/F-30

FIGURE F-30. LIGHT DEBRIS CONCENTRATED IN CORNER OF SLIP, SEATTLE

TABLE F. (Continued)

Debris Encountered by Category	Description
Non-Rigid Shapes	Life jackets, rolled sleeping bags, shoes, and cardboard boxes are found floating in the Seattle area. These items would normally be encountered one item at a time.
Rigid Shapes	Cork, floats, burnt flares, pieces of boats, whole derelict boats, automobile and truck tires, whole banded groups of logs, houseboats, and pieces of furniture occur in the Seattle/Tacoma area. These items would also be found one item at a time.
Flexible Sheets	Visqueen plastic sheets of all sizes are found here and there floating in the water. Some sheet paper and cardboard is also found.
Rigid Sheets	Hatch covers and plywood pieces of various sizes are found one item at a time.
Filamentous Pieces	Kelp is found throughout the Sound in pieces or growing in groups. Some kelp would be encountered in the open waters of the Sound near Seattle or Tacoma in a spill.
Special Cases	Bottles, cans, baseballs, tennis balls, light bulbs. oil drums, LNG tanks, milk cartons, and paper cups are found one item at a time in the Seattle/Tacoma area.

TABLE F. (Continued)

Debris Encountered by Category	Description
Northwest Region - Bellingham/Everett Port Areas	
General Wood Items	The main sources of debris in Everett and Bellingham are related to logging. The same types of debris are found in these ports as are found in Puget Sound. The concentration of material, however, is greater in Everett and Bellingham because of the large quantity of log rafts transported in these ports. Large amounts of bark chips, loose logs, and slash material occur in these ports. In one 3-month period, 39,375 cubic feet of unmarketable logging slash debris alone was collected by an Everett contractor working for the State of Washington[(1)].
Other Categories	Very little debris other than wood is found in these harbors. For a description of the other types of debris that can be found, see the Puget Sound discussion.
Pacific Ocean Region	
General	As of now, limited data are available concerning the type and quantity of debris in the Pacific Ocean. One

(1) Conversation between American Tugboat Company, Everett, Washington, and Battelle-Long Beach (November 13, 1973).

TABLE F. (Cont' .ed)

Debris Encountered by Category	Description
General (Continued)	reference -- a report on the material observed during a Scripps Institution expedition in the Pacific--was published in 1973[1]. On this expedition, objects such as fishing floats (5 to 14 inches in diameter), bottles (glass and plastic), fragments of plastic bottles, rope, rubber sandals, paper items, and other articles were observed at an average frequency of one every 12 minutes. This quantity of debris would be of minor concern in an oil spill and is small when compared to the situations that develop in harbors and other areas where a great deal of concentrated local activity takes place.
	Honolulu, Hawaii Area
General Wood Items	Some wood enters the Hololulu shorefront area from the adjacent hills. Most is natural wood, consisting of branches and trunks of trees. Normal quantities on the water are light but can be moderate when southern winds bring material trapped under docks out in fairly large quantities. (Normal trade winds are northeasterly.) Most wood items are small or medium sized.

(1) Venrick, E. L., et al, "Man Made Objects on the Surface of the Central North Pacific Ocean", Nature, Vol. 241 (January 26, 1973).

TABLE F. (Continued)

Debris Encountered by Category	Description
Other Categories	Some municipal debris, such as bottles, cans, and paper washes down into the harbor after heavy rains. Coconuts, palm fronds, tropical plants, and leaves also enter the shorefront area after storms.
	Pearl Harbor, Hawaii Area
General Wood Items	Some floating wood is found in Pearl Harbor. Most is natural wood -- tree limbs and branches -- that comes down out of the mountains after heavy rains. Estimated sizes range from 3 to 10 feet in length and 1 to 6 inches in diameter(1).
Other Categories	Other debris in Pearl Harbor consists of material discarded from Navy ships in the port. Items include paint cans, beer cans, soda cans, rags, and pieces of plastic. Concentrations of debris occur underneath wharfs and docks. The Navy conducts a regular harbor-cleanup operation which picks up an estimated 1,300 cubic feet of debris weekly, mostly rubbish(2). On severe days when the wind shifts and brings material out from under the docks, an estimated 2,200 to 2,400 cubic feet of debris is picked up daily(3). In past

(1) Conversation with Shop 02 Personnel of the Navy in Pearl Harbor (March 7, 1974).
(2) Ibid.
(3) Ibid.

TABLE F. (Continued)

Debris Encountered by Category	Description
Other Categories (Continued)	small oil spills, no difficulty with debris has occurred while picking up the oil with a small floating skimmer. (Debris mixed in with the spill is recovered using a hand skimmer).

APPENDIX G

MAJOR OIL SPILLS

Appendix G contains descriptions of 12 major oil spills that have taken place in the United States. Both spills where debris was a problem and spills where there were no significant concentrations of debris are described.

APPENDIX G

A. MAJOR OIL SPILLS

This Appendix discusses the methods and equipment used to handle debris in selected major oil-pollution incidents. Where possible, the equipment and techniques used are described in terms of the design and performance considerations given in Chapter III.

1. San Francisco Bay Tankers Collision

At about 1:45 a.m. January 18, 1971, two oil tankers, the Oregon Standard and the Arizona Standard, collided in the fog near the Golden Gate Bridge in San Francisco Bay. The Oregon Standard spilled approximately 20,000 barrels of bunker fuel into the Bay. The Standard Oil Company of California had a contingency plan, based on just such an incident, which went into effect immediately. The ensuing cleanup effort has been well documented in various newspaper and magazine articles as well as in industry and Coast Guard reports.

During the first few hours of the cleanup, there was little need for debris-handling equipment. During the later stages, however, the oil--which had begun to take on a putty-like consistency--mixed with the naturally occurring debris of the Bay and the tons of straw which were spread on oil slicks and along beaches in an effort to reduce oil damage to the environment. Several pieces of oil/straw/debris-recovery equipment were pressed into service; in fact, of the 23 major oil-recovery devices used during the 9-day cleanup, eight were used specifically for picking up oil-soaked straw and debris.

The barge, Healy-Tibbitts No. 9 (see Figures G-1 and G-2), was on the scene early and as a result picked up more oil-soaked straw than any other rig. It consisted of two barges lashed together to form an open "V" which collected and concentrated oil and straw as the barges were moved forward by a pusher tug. A crane with a clamshell bucket mounted on the larger (200-foot length by 40-foot width) barge dipped oil/straw/debris out

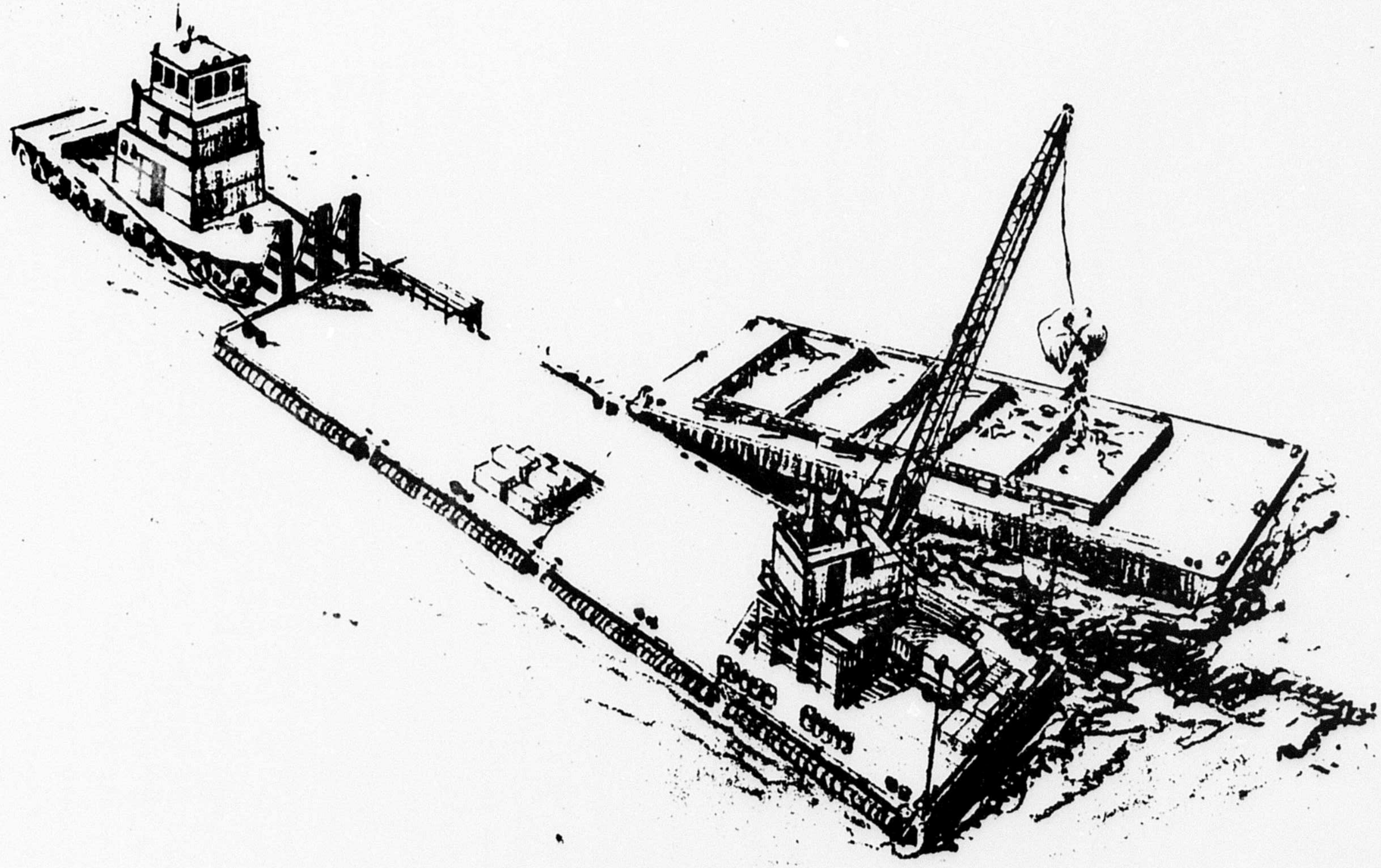


FIGURE G-1. HEALY-TIBBITTS NO. 9, SKETCH[1]

(1) Boydston, B. D., "Golden Gate Oil Spill", report for Standard Oil Company of California, (March 24, 1971), p. F-33.

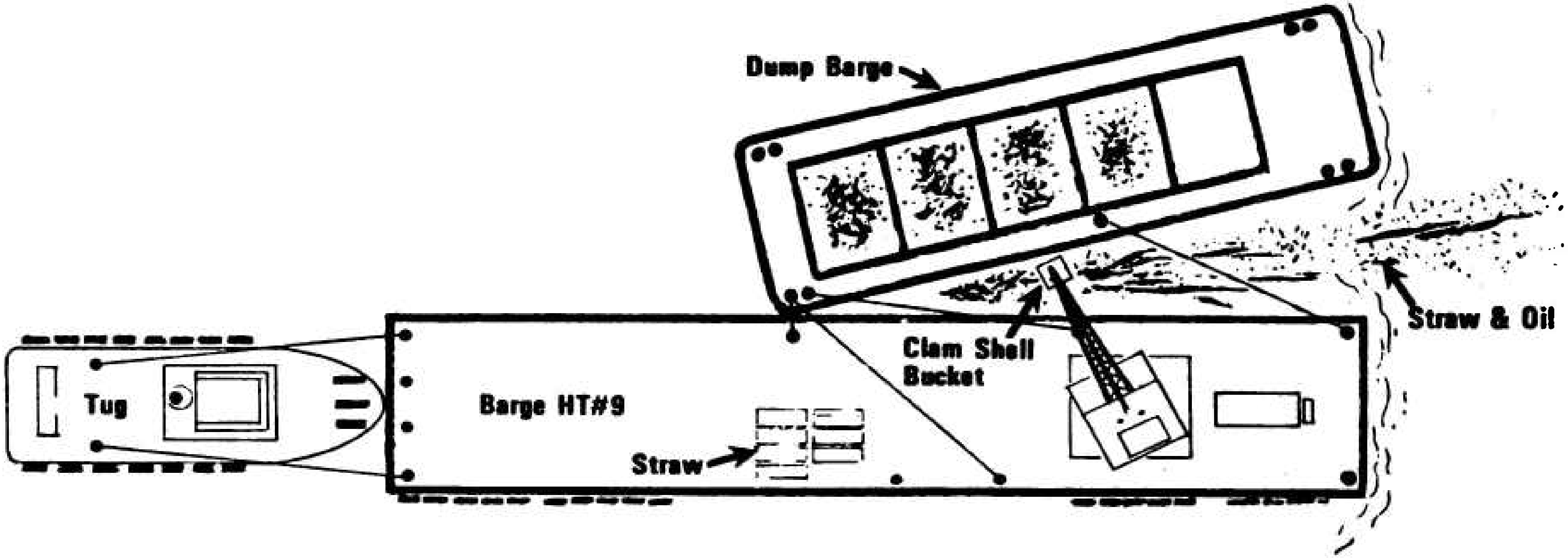


FIGURE G-2. HEALY-TIBBITTS NO. 9, SCHEMATIC[1]

(1) Boydston, op cit, p. F-34.

of the "V" and loaded it into the scow barge. The extensive deck space on the large barge was used to store additional hay bales to be spread on slicks and open-top barrels to be hand-loaded with oil/straw/debris. It was also used as a base for deploying portable skimmers and for temporary oil storage tanks. The extensive storage capacity of the scow barge gave this rig excellent on-scene staying time. This rig was not suited for open-sea operation, but it could be easily maneuvered and kept on station in heavy concentrations of oil/straw/debris, and the crane with clamshell could be operated over the top of a containment boom.

Duncanson-Harrelson No. 16 (see Figures G-3 and G-4) consisted of a barge-mounted crane alongside a scow barge with a tugboat for propulsion. A specially made 40-foot-long basket of wire mesh over a steel-pipe frame was positioned by the crane over the forward end of the barge to collect oil/straw/debris which was then dumped into the scow. This rig was very effective; and had it been on the scene earlier in the cleanup effort, it probably would have collected more oil/straw than the Healy-Tibbitts No. 9. Like the Healy-Tibbitts No. 9, this rig was not suitable for open-ocean operations and had to be pushed forward through the slicks for best results.

The most versatile rig was the Rig Engineer (see Figure G-5), which consisted of two Gradall G-800 hydraulically actuated, truck-mounted backhoes with basket scoops, mounted on the deck of a 140-foot-long by 30-foot-wide work boat. Equipped with twin screws and a bow thruster, the Rig Engineer had a top speed of 16 knots and excellent maneuverability, making it extremely effective in chasing down and collecting scattered oil/straw/debris patches in the later stages of the cleanup. With the Gradalls moving about on its deck, the Rig Engineer was able to position itself in one spot and collect debris without having to move. This feature would be valuable in a case where the debris collection had to be done over the top of a boom or barrier. In addition, the Rig Engineer was capable of recovering oil/straw/debris in 3-foot waves, making it one of the few rigs with some open-ocean capacity. Had it been on-scene from the beginning, it would undoubtedly have recovered as much oil/straw/debris as the other rigs. These three massive rigs were capable of recovering 100 to 200 tons of oil/straw/debris in 12 hours.

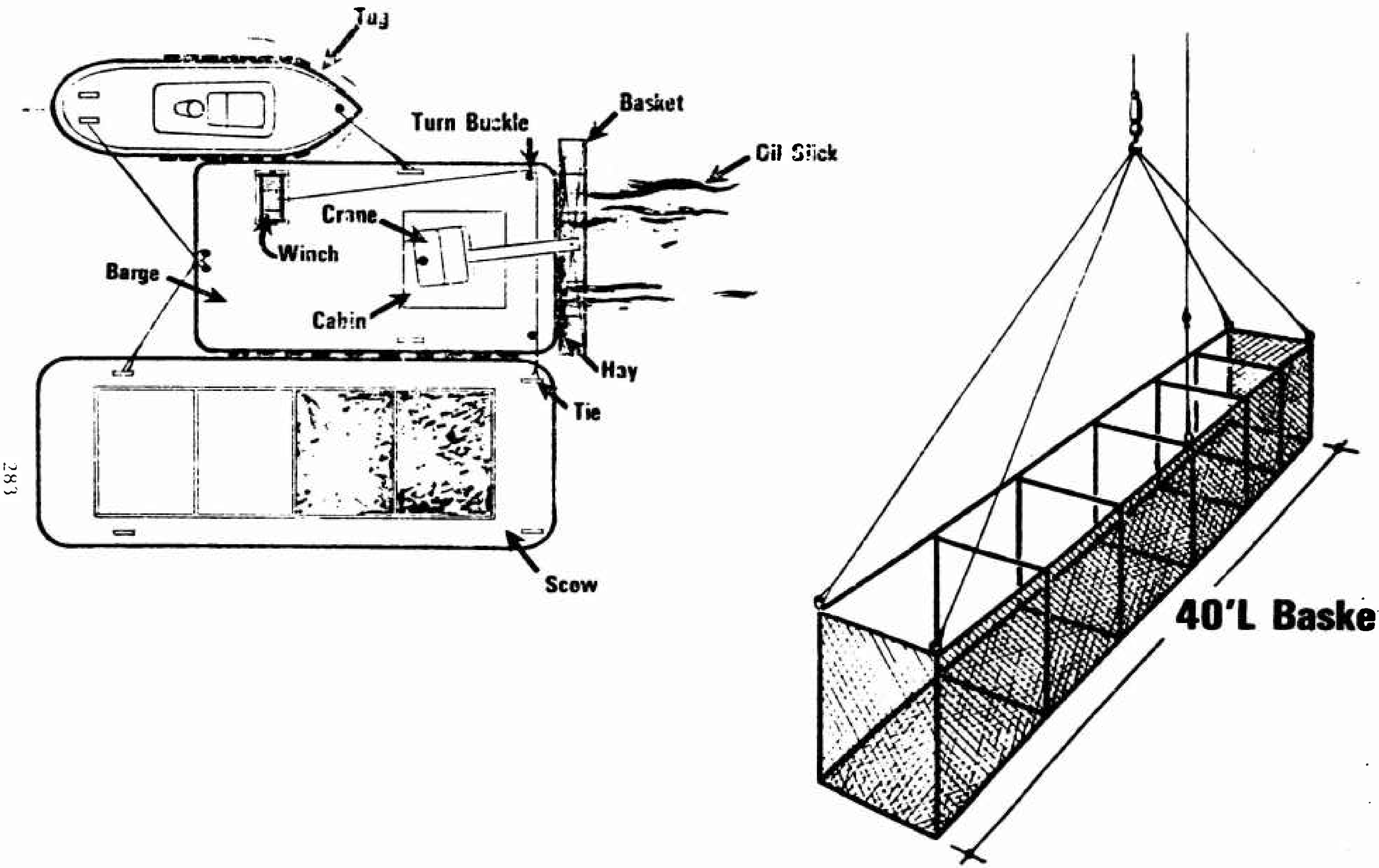


FIGURE G-4. DUNCANSON-HARRELSON NO. 16, SCHEMATIC[1]

(1) Boydston, op cit, p. F-25.

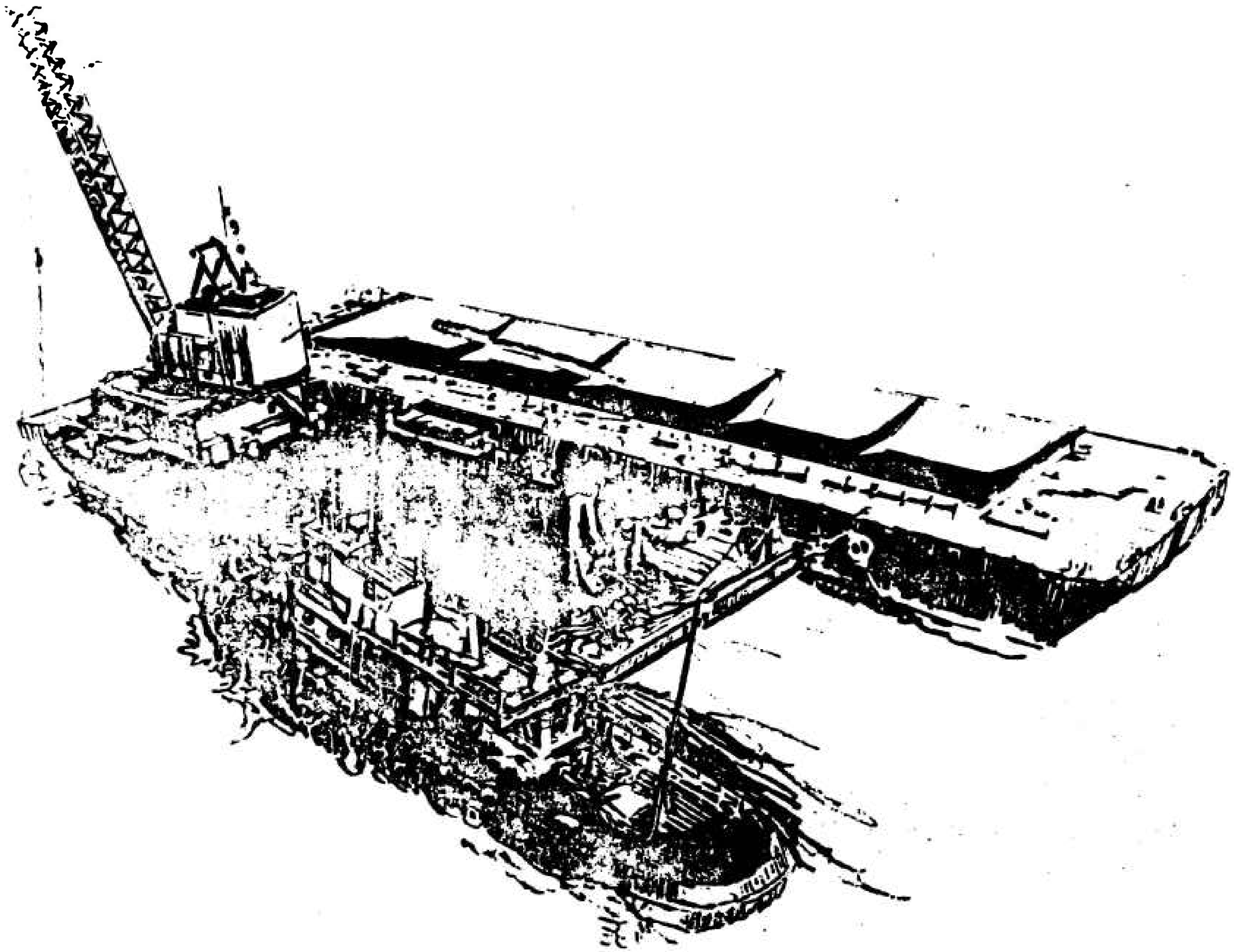


FIGURE G-3. DUNCANSON-HARRELSON NO. 16, SKETCH[1]

(1) Boydston, op cit, p. F-24

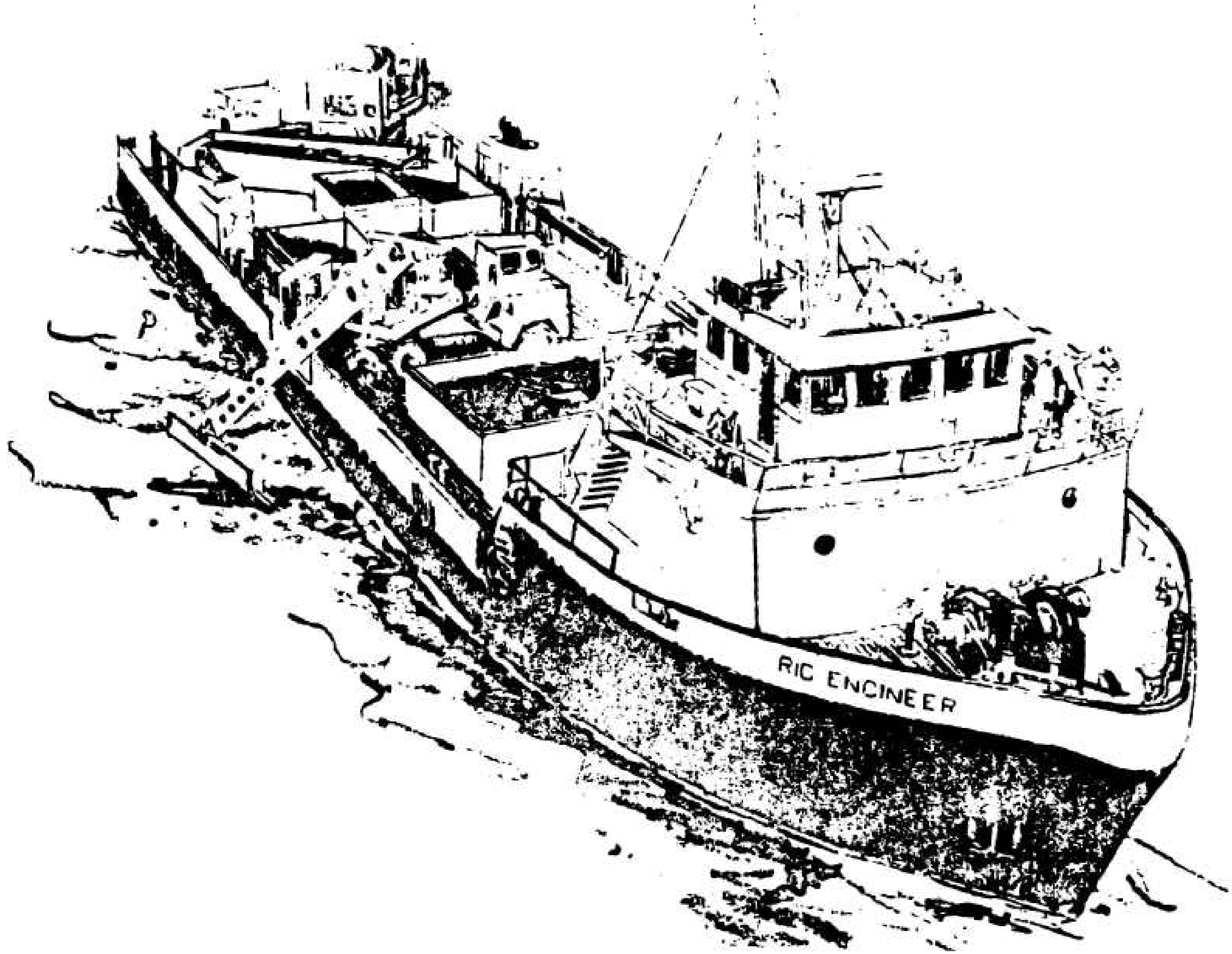


FIGURE G-5. RIG ENGINEER [1]

(1) Boydston, op cit, p. F-30.

The Corps of Engineers' debris boats were also used to collect patches of oily straw and debris, but they were not as effective as the larger rigs, primarily because of their relatively limited storage capacity. This storage capacity was augmented, however, by dumping onto the scow barges. The Coyote and Raccoon, designed specifically for collecting large items of debris in the Bay, were most effective when used to chase down and gather scattered patches and windrows of oily scum, straw, and debris. Although not suited for the open sea, these boats have enough speed and maneuverability to cope with the 6-knot currents common in San Francisco Bay.

The other three "straw-picking" rigs were basically smaller versions of those described above, but they were less effective because of their smaller collection baskets, limited storage capacity, and reduced speed and maneuverability. None of the mechanized debris-collection rigs were able to operate in the extensive shallow areas of the Bay. Where the water was only 1 or 2 feet deep, oily straw and debris were picked up by laborers working out of scores of small skiffs or wading, using pitchforks, shovels, rakes, hoes, and their bare hands to load open-top 55-gallon drums, baskets, and barrels. Cleanup work around piers and docks consisted of basically this same kind of manual operation (see Figures G-6, G-7, and G-8), but also included the use of an LCM with a sorbent/debris conveyor mounted on its loading ramp. The LCM (see Figure G-9) was able to maneuver easily in confined areas; but, with its bow door down, it was limited to very calm waters, and its rate of recovery of oily straw and debris was very low compared to the larger rigs used out in the Bay.

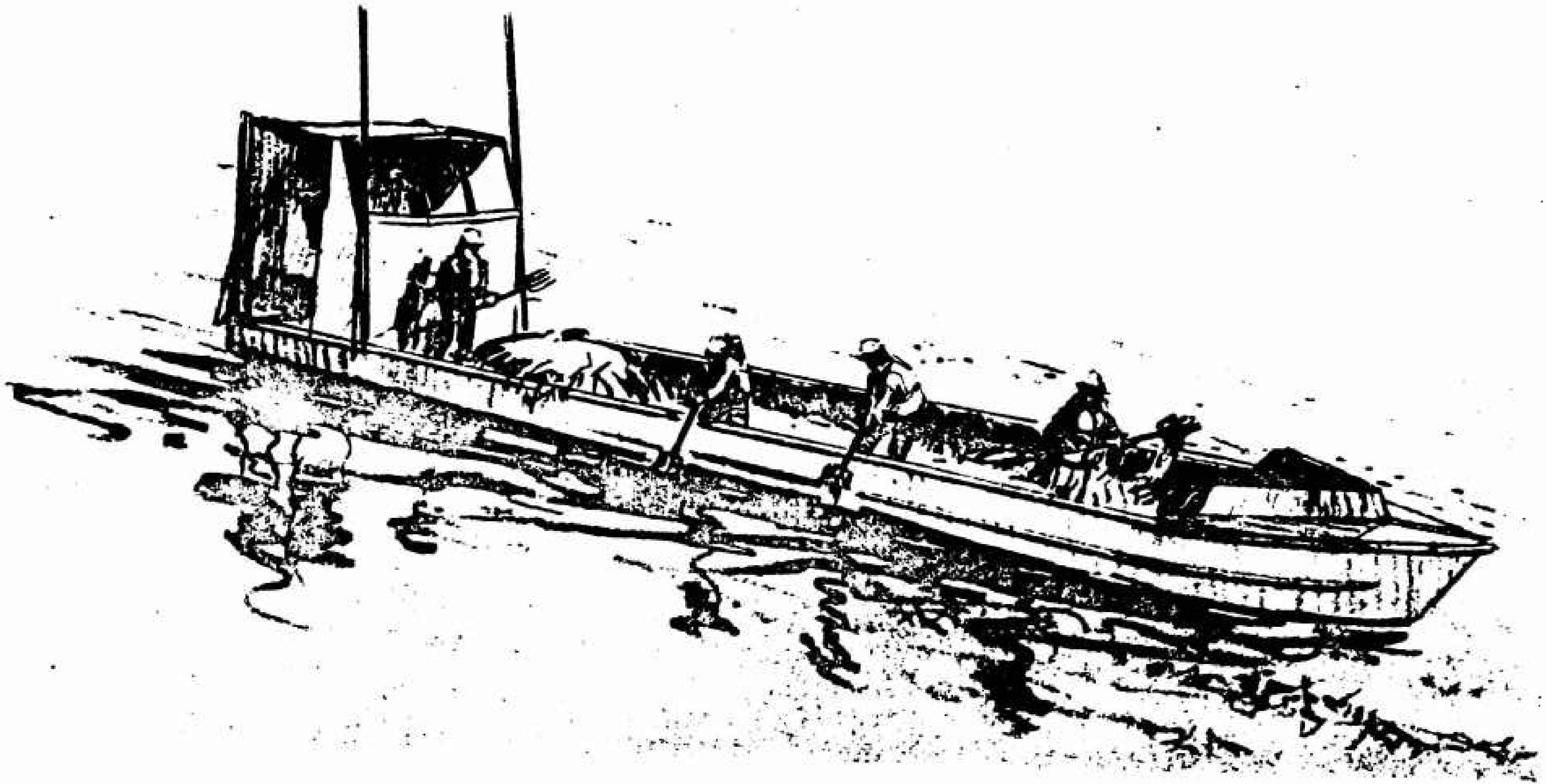


FIGURE G-6. STRAW PICKER FIBERGLASS BARGE[1]

(1) Boydston, op cit, p. F-26.

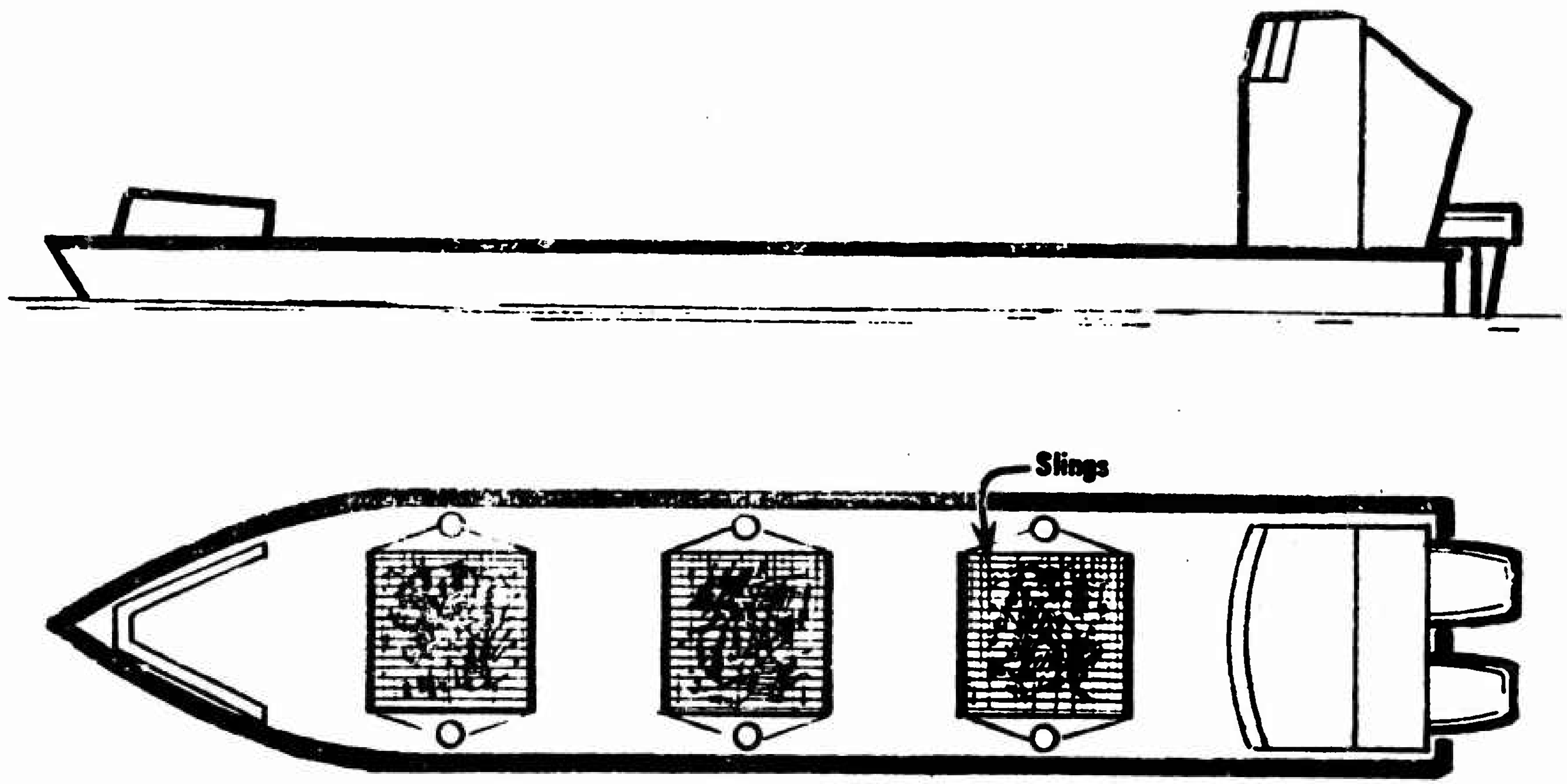


FIGURE G-7. STRAW PICKER FIBERGLASS BARGE 42'L x 12'W, OUTBOARD MOTOR POWER[(1)]

(1) Boydston, op cit, p. F-27.

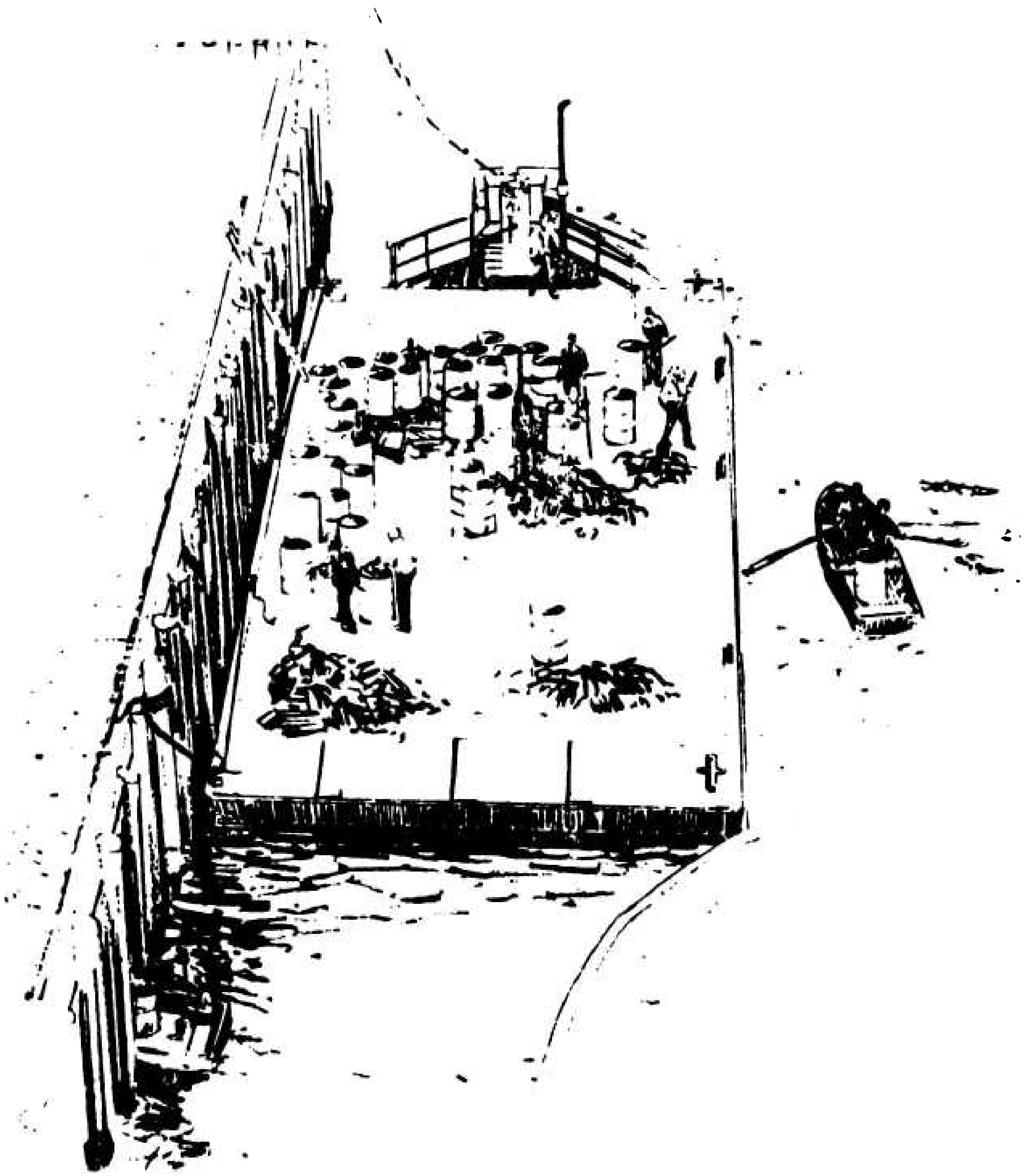


FIGURE G-8. DEBRIS BARGE WITH SKIFFS FOR CLEANUP AROUND DOCKS (1)

(1) Boydston, op cit, p. F-55.

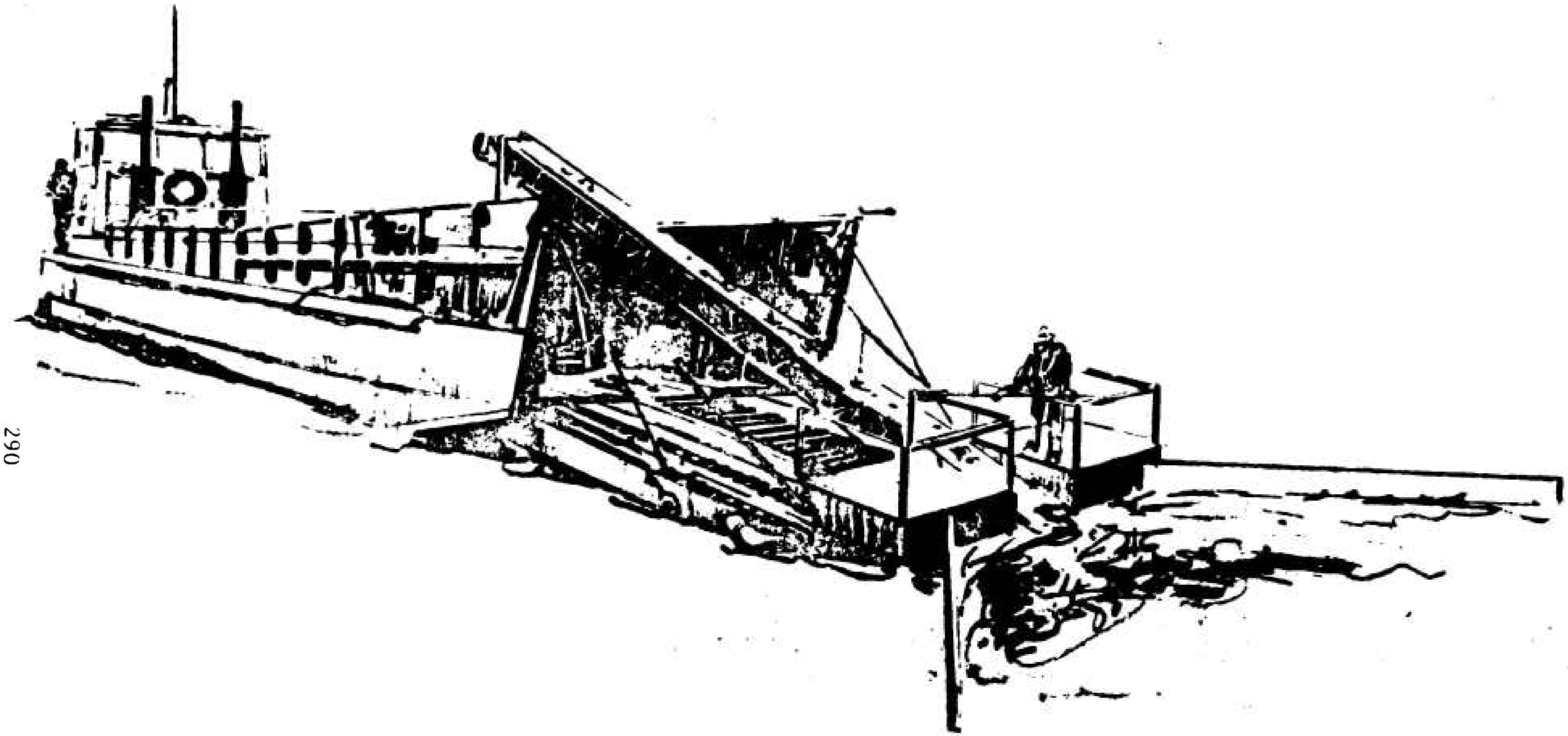


FIGURE G-9. STRAW PICKER LCM WITH CONVEYOR (1)

(1) Boydston, op cit, p. F-28.

2. Oakland Estuary Spill

The spillage of some 171,000 gallons of reclaimed crankcase oil into the Oakland Estuary on the night of January 18, 1973, resulted in what has been called a "classic oil and debris cleanup problem"(1). During the cleanup effort, which lasted 7-1/2 days and is described in great detail in Reference 2, some 1,400 cubic yards of oil-soaked debris were removed from the 3-mile stretch of waterway, loaded into trucks, and disposed of in an approved dump.

The Corps of Engineers' debris boats were very effective in recovering large items of debris from open water in the estuary. Their debris nets were sometimes lined with commercial oil sorbents and straw to aid in picking up patches of oil. The limited storage capacity of the Coyote and Raccoon was augmented by placing large trash barges at strategic points along the waterway where the boats could offload. These two boats recovered more oily trash and debris than any of the other rigs.

Six cranes equipped with clamshell buckets, including one mounted on a barge, were stationed at sites along the estuary where skimming operations were conducted, or where the greatest concentrations of debris were found (Figure G-10). Most of the debris dipped out of the water was loaded directly into dump trucks, which carried it to the disposal dump approved by the Regional Water Quality Control Board. Some of the debris was hauled to an approved dump site by the 1,500-cubic-yard trash barge loaded at Ninth Avenue Pier. The clamshell buckets worked well as long as the debris could be concentrated in one area near shore. Specialized equipment, such as log grapples, for handling large timbers, were not considered to be necessary(3).

Fleets of small skiffs and workboats were deployed along the highly developed shoreline to clean up around piers and in small boat marinas. Workers used pitchforks covered with wire mesh to hand-load oily debris into

---

(1) Meeting with LCDR John Wiechert, Commanding Officer, U. S. Coast Guard, Pacific Strike Team, San Francisco, CA (December 26, 1973).

(2) Clean Bay, Inc., "Cleaning Up the Oakland Estuary Spill January 19-26, 1973" (1973).

(3) Telephone conversation with CDR Gordon Dickman, MEP, 12th Coast Guard Dist., San Francisco, CA (February 7, 1974).

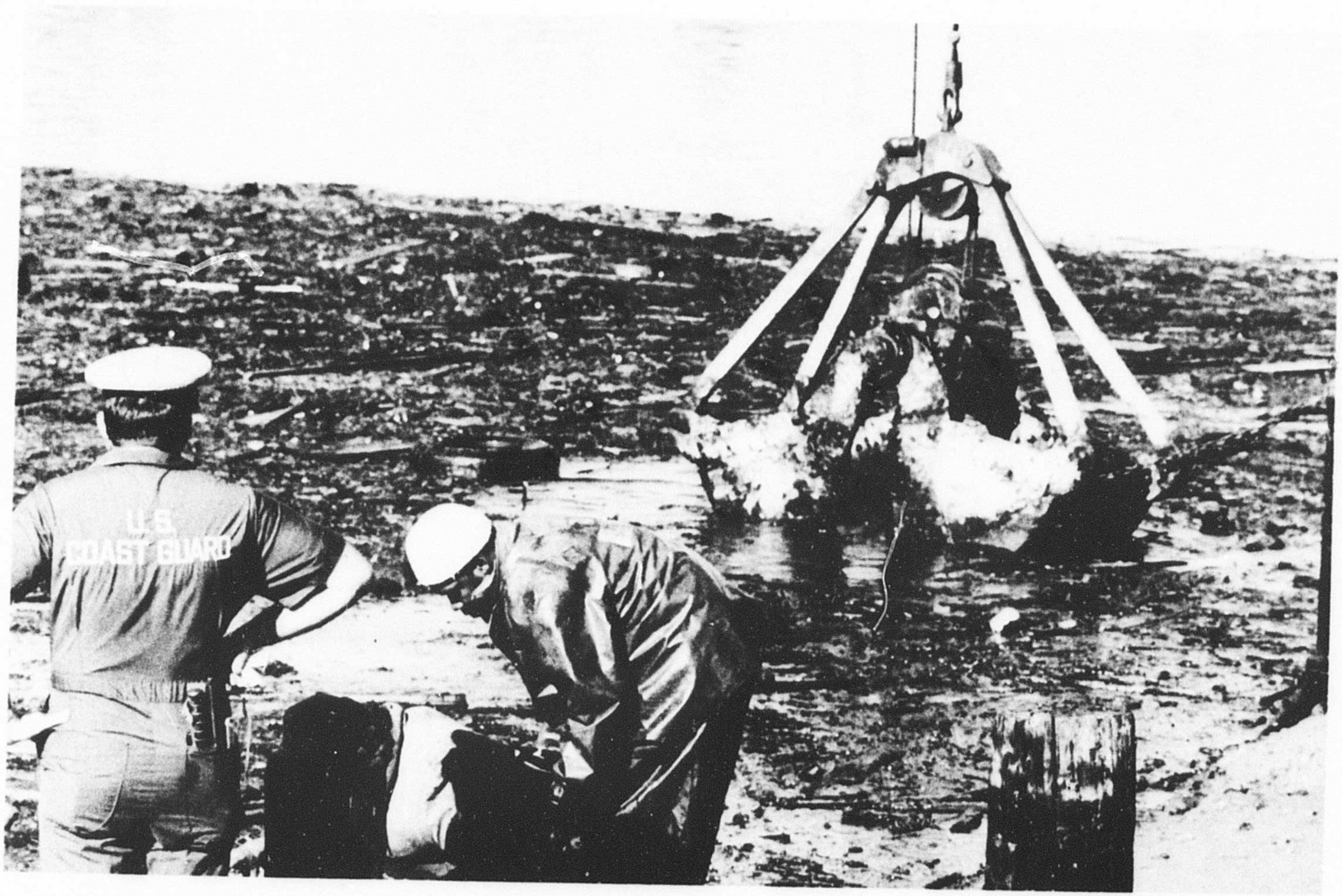


FIGURE G-10. CLEARING OILY DEBRIS WITH CLAMSHELL BUCKET, OAKLAND ESTUARY(1)

(1) 12th Coast Guard District, San Francisco, CA, Official Photo, File No. 012073 14.

barrels, or simply into the bottoms of their boats. Workers with mesh-covered pitchforks were stationed at skimmer locations to manually remove debris from the skimmer suctions.

The propeller wash from tugboats tending the booms deployed across the Estuary helped to divert oil/debris away from direct contact with the boom and over to the Oakland shore, where it was picked up by clamshell. Towing one end of the boom with a boat also enabled the barrier to be adjusted more easily when the tidal currents changed. Propeller wash from large tugs was also used to flush out oil/debris from underneath piers, but high-pressure water hoses and tidal action worked better in these situations.

3. San Juan River Spill

On October 10, 1972, slightly less than 7,000 barrels of crude oil spilled from the damaged Aneth pipeline west of Shiprock, New Mexico. Much of it found its way into the San Juan River, which flows into Lake Powell. Some was recovered near the spill site, but the major cleanup effort was centered far downstream in the upper reaches of the San Juan River arm of Lake Powell.

Oil hit the first containment boom that was placed across the river on October 13, and nearly 5 acres of debris collected behind the boom. Flood currents up to 4 knots, due to constant rains in the area, however, caused the boom to break. Operations were moved some 4 miles downstream to deeper water where the currents ran much more slowly (1 to 1-1/2 knots). Booms were again deployed, but this time they were used to divert the oil-soaked debris to quiet waters along the river bank. The most successful booms were those constructed at the scene using large logs, 20 to 28 inches in diameter and 40 feet long, which were chained end to end. One end of the boom was fastened to shore and the other to a small outboard-powered boat which maneuvered in the river to catch patches of debris and divert them toward shore. Several outboard motors were burned out doing this heavy work.

On shore, two cranes brought in by LCM picked debris out of the water with clamshell buckets and loaded it directly into dump trucks which took it to bulldozed disposal pits. In later stages of the cleanup operation, which lasted through December 21, specially designed dragline baskets were constructed at the scene from steel tube and wire fence and were mounted on the cranes. Debris was then scooped out of the river and dumped on the shore where a large front-end loader scooped it up and loaded it into dump trucks. This method was more efficient than emptying the clamshells directly into the trucks. Some attempts were made to use agricultural slurry pumps to pump water/oil/debris out of the river and into specially constructed dikes on the riverbank and to trap oily debris by allowing the water to run out the bottom, but these methods failed because the flow broke down the earthen dikes. Attempts to burn the oily debris on-scene failed because of constant rain which soaked the already wet debris. It was finally disposed of in two large bulldozed pits.

The single road to the remote cleanup site was impassable due to rains and flooding, so helicopters and an LCM were used to bring in equipment and material. CH-47 Chinook helicopters brought in the 2-ton logs for the log boom two at a time. Some large items of debris-handling equipment could not be brought to the scene because they were either too large for the LCM or too heavy for the helicopters. In general, it took at least 24 hours to get a desired piece of equipment to the scene.

It is estimated that the cleanup cost was between $750,000 and $1,000,000. During the 3-1/2-month operation, an estimated 25,000 cubic yards of oil-soaked debris was recovered. Of the oil spilled, approximately 1,000 barrels were recovered with the debris. The debris-cleanup operation was fairly thorough, but it was "painfully slow"[(1)], considering the amount of debris encountered, the flooding, and the problem of accessibility to the site.

Secondary effects to the environment were kept to a minimum by operating mainly in areas which will be underwater when Lake Powell is filled.

---

(1) Telephone conversation and visit with LCDR Wiechert, U. S. Coast Guard, Pacific Strike Team, San Francisco, CA (December 1973).

Care was taken to avoid damage to adjacent Indian land; and, after the operation was terminated, 2 days were spent improving the access roads which had been constructed in the immediate cleanup area.

4. Schuylkill River Spill, 1970

There have been two major oil spills in the Schuylkill River in the past few years, and both have been accompanied by severe debris problems. The first occurred on November 13, 1970, when, after several days of very heavy rain, an estimated 3,000,000 gallons of oil/water mix in the Berks Associates' settling lagoons overflowed the earthen dikes and spilled into the River. This spill and the subsequent 12-day cleanup effort are reported in Reference 1.

Early attempts to contain the oil by placing booms directly across the river failed repeatedly because the swift current (3 knots) and heavy accumulations of debris caused the booms to part. Eventually, plans were made to place a diversionary boom across the Schuylkill at the Pennrose Avenue Bridge in Philadelphia, some 30 miles downstream from the original site, where the current was much slower. The boom was finally put in place (about 26 hours after the spill occurred) to divert oil/debris into a quiet cove near the bridge where an on-shore crane with clamshell bucket hauled out the debris. Oil skimmers were then put into operation. The Corps of Engineers' dredging barge was placed midstream to anchor one end of the diversionary boom, and a small outboard workboat was used to open and close the boom to allow workboats to cross (Figure G-11). A diversionary boom was also placed at Fort Miflin, on the Delaware River, where an on-shore crane with a clamshell hauled out debris.

The Commonwealth of Pennsylvania's debris boat, Sheriff (described earlier), was put into service recovering debris from the boomed area at Pennrose Avenue Bridge and loading it aboard a Corps of Engineers barge.

---

(1) Division of Oil and Hazardous Materials, Office of Water Programs, Environmental Protection Agency, "Oil on the Schuylkill" (undated).

FIGURE G-11. OIL AND DEBRIS COLLECTING NEAR PENNROSE AVENUE BRIDGE, SCHUYLKILL RIVER, PHILADELPHIA[1]

(1) Official photograph, U. S. Coast Guard.

The Sheriff worked particularly well because its hydraulic loader was able to reach over the boom to pick up debris. In all, 828 tons of debris were recovered at the Pennrose Avenue Bridge site.

Upstream of the Bridge, a filter fence of steel-reinforced cyclone fence was emplaced against the upstream side of another bridge to trap debris and keep it from hindering the oil-recovery operations downstream. This worked well, as it allowed oil to flow downstream to the skimmer site. It should have been done earlier in the cleanup effort.

At abandoned Lock 60 of Black Rock Dam, upstream of Philadelphia, a huge amount of oily debris had gathered in the natural pocket formed by the lock. A trash rake built at the scene was used to manually haul out debris at this site[1]. This was one of many natural catch basins for oil/debris which could have been used effectively in conjunction with diversionary boom to collect oil/debris far upstream of Philadelphia. At many small coves and curves in the river, pockets of oil and debris had collected. Water hoses were used to flush this oil/debris out into the main stream and down river to boomed off areas.

5. Schuylkill River Spill, 1972

The second major Schuylkill spill occurred during the floods caused by Hurricane Agnes in June, 1972, and again involved reclaimed crankcase oil from Berks Associates' reservoirs--this time some 6,000,000 gallons. A diversionary boom was again emplaced at the Pennrose Avenue Bridge site in Philadelphia, and cranes and the Commonwealth boat, Sheriff, were used to clean up debris. The boom required constant tending and periodic maintenance throughout the 3-month cleanup operation. A large amount of debris was handled at the boom site by manual laborers with rakes and pitchforks.

The flooding was so severe that much of the debris-handling effort involved gathering oil-soaked vegetation, soil, and other debris from the riverbank, from islands in the River, and from the flood plain along the

(1) Environmental Protection Agency, op cit.

River up to several hundred yards from the riverbank itself. The major portion of this cleanup involved manually picking up debris and loading it into barrels, baskets, wheelbarrows, and trucks with shovels, rakes, and pitchforks. In some cases teams of farm horses were brought in to pull dragline buckets along the shoreline, but for the most part, heavy mechanized equipment was not used because of the damage it would have caused to the marshy, unstable soil. At places along the River where the soil was firm enough, or where there were roads, piers, or landings along the bank, large stake trucks with powerful winches were used to pull out large logs and tree limbs. Boom cranes on the trucks then hoisted the large, heavy items of debris aboard. In a few areas, bulldozers and front-end loaders were used to collect debris. At the peak of the cleanup operation some 500 people were employed.

The oil-soaked debris was loaded into dump trucks which then drove up a ramp over a railroad siding and dumped the debris into waiting hopper cars. The hopper cars, which were sealed to prevent oil leakage, were taken to an approved disposal area and dumped. In all, some 200 hopper-car loads of oily debris were disposed of in this manner.

Except for the operation at the Pennrose Avenue Bridge site, nearly all the debris was collected by shore-based operations. This was due primarily to the fact that the River was in flood stage at the start of the cleanup effort, and any large barges or boats could have been left aground as the floodwaters gradually receded.

One interesting technique which was used as the flooding subsided was to place filter fences at the mouths of small streams that entered the Schuylkill. These fences--which consisted of cyclone fencing supported by steel fence posts and reinforcing rod, and lined with sorbent pads--captured much of the oily debris and sludge before it could find its way back into the River from the flood plain.

Thousands of 55-gallon steel drums were washed downstream in the flood, and these were particularly hard to handle because many were full or half full of paint, chemicals, and other hazardous materials. The Sheriff, with its hydraulic front-end loader, was best suited for recovering these drums. Most of the drums were stored at Fort Miflin for later disposal, and many were returned intact to their original owners.

6. Casco Bay, Maine, Spill

Early on the morning of July 22, 1972, the Norwegian Tanker, Tamano, inbound for Portland, Maine, with 543,000 barrels of No. 6 fuel oil, struck bottom in Hussey Sound, rupturing one of her starboard wing tanks. Best estimates indicate that 100,000 gallons of fuel oil escaped, and that some 70,000 gallons were recovered in the subsequent cleanup efforts. Early deployment of containment booms around the Tamano reduced debris-handling problems to a minimum within the boomed-off area and allowed efficient use of skimmers. A major portion of the 30,000 gallons which was not recovered by skimming hit the beaches of the Maine Coast and the islands in and around Casco Bay, requiring an extensive beach cleanup project which lasted until October 16, 1972. A detailed account of the spill cleanup operation can be found in Reference 1.

The major debris problems in this spill were caused by hay and straw which were spread on the oil slicks outside the boomed area surrounding the Tamano, and by seaweed and eel grass which became mixed with the oil. Nearly all of the floating, oily debris was recovered by capturing the oil/debris patches in boom catenaries towed by small boats, reducing the area enclosed by the boom to concentrate the oil/debris, and dipping the oily debris into open-top barrels by hand using pitchforks, rakes, and shovels. Virtually no mechanized debris-handling equipment was used to remove the debris from the water. The barrels of oil/debris were hoisted from work boats to barges, offloaded from the barges by cranes, and then loaded onto trucks for transport to a disposal site. The basic debris-recovery technique was manual labor.

The cleanup of oil-contaminated beaches, in the weeks following the recovery of oil and oily debris actually floating in the water, involved bulldozers, front-end loaders, dump trucks, and several cranes; but this part of the operation did not involve removing debris from the water. The

(1) USCG Captain of Port, Portland, ME, "On-Scene Coordinator's Report, Major Oil Spill, Casco Bay, Maine, 22 July, 1972"(1972).

problem of locating a suitable disposal site for the oil-soaked debris was a major one, as discussed in the on-scene commander's report[1].

A lack of sufficient on-scene temporary storage capacity for oily debris was a problem in this spill, as it has been in others. Debris-recovery operations were slowed because of the lack of barrels available for oil/debris, and workers had to cease work while the full barrels were barged to a [illegible]er, emptied, and returned.

The State of Massachusetts' JBF DIP-2001 skimmer was used fairly successfully in recovering patches of oil and oil-soaked straw. It was towed alongside a 35-foot steel tug while oil and debris were gathered in its 4 by 5-foot collection well. The oil/debris was loaded manually into open-top barrels which were transferred to the tug and then to a barge alongside the Tamano. The major difficulty here again was the lack of on-scene temporary storage capacity. The operation of the JBF skimmer is well detailed in Reference 2. Recovery of straw, seaweed, eel grass, and small categories of debris was quite good with the DIP-2001; but large items of debris, such as heavy timbers, could not be handled and might even have caused damage to the moving inclined plane, its rollers, and drive sockets.

7. USNS Towle Spill

On the evening of July 14, 1971, the USNS Pvt. John R. Towle was transferring Bunker C fuel oil at the Marine Ocean Terminal(MOT), Bayonne, New Jersey, when the engineer in charge mistakenly aligned the flow to an overboard discharge. The mistake was not noticed until several hours later, and the Navy later estimated that 900 barrels of fuel were spilled. The initial delay in discovering the spill and subsequent delays in deploying enough boom to surround the ship and MOT pier, where the slicks were thickest, allowed the oil to spread extensively throughout parts of New York

---

(1) USCG Captain of Port, Portland, ME, op cit.

(2) Bianchi, Ralph A., et al, "Use of the Massachusetts DIP Oil Skimmer on Free Slicks in the Casco Bay (Portland) Spill", in Proceedings, Joint Conference on Prevention and Control of Oil Spills, sponsored by API, EPA, USCG (1973).

Harbor. Reference 1 gives a detailed account of the problems involved with the spill-cleanup effort.

All of the oil-skimming operations were centered in the boomed-off area around the Towle and the MOT pier. There was little need for debris-handling equipment inside the boom, which kept this area relatively free of waterborne drift and debris. Vacuum hoses and a Reinwerft 1000 skimmer were used to recover oil inside the boom. In later stages sorbents were scattered on the thin rainbow slicks inside the booms, and vacuum trucks with large (12-15 inch) intakes had no difficulty in recovering the large quantities of oil-soaked sorbents (both "Stricktite" and "Sorbent-C" were used). There was, initially, some problem in clearing oil out of storm drains in the pier and from under the pier, due to blockage by debris (trash, leaves, small categories); but high-pressure water hoses from New York City fireboats and propeller wash from tugboats tied to the pier were used to successfully flush oil and debris from these areas.

Outside the boomed area, the cleanup effort consisted almost entirely of dealing with oil which came ashore on the beaches at Coney Island, Staten Island, Seagate, and elsewhere. Apparently no attempt was made to chase down and recover free-floating slicks in the harbor. Beach cleanup consisted basically of manually raking and shovelling oil-soaked sand, seaweed, driftwood, and trash into rows parallel to the waterline, then using front-end loaders to scoop up the rows and load the oily debris into dump trucks. Bulldozers were used on 3.5 miles of Coney Island beach to construct berms which collected oil/debris as the tide flowed in and allowed water to filter out on the ebb tide, trapping oil and debris which was cleaned up by laborers and front-end loaders. On Staten Island similar operations on a smaller scale yielded 27 truck loads (20 cubic yards each) of oil and oil-soaked material.

Equipment for beach cleanup included front-end loaders, bulldozers, 2.5-ton trucks from various departments of the City of New York and civilian contractors. Manpower included Coast Guard and Naval reservists, on-duty

---

(1) Hanson, R. J., CDR, USCG, "On-Scene Commander's Report, USNS Towle, Oil Pollution Incident, New York Harbor, 14-28 July, 1971" (December 1971).

Coast Guard personnel, and 100 city employees. Many of the hand tools (rakes, shovels, pitchforks) were purchased specifically for the cleanup job from Coast Guard contingency funds. The cleanup effort was completed on July 27 at a total cost of $470,000.

8. Santa Barbara Channel Spill

The Santa Barbara Channel oil spill started on January 28, 1969, when gas and oil began leaking from a 1,200-foot-long fissure on the ocean floor in 190 feet of water 6 miles southeast of Santa Barbara. The leak continued for several months, and the resultant cleanup operation was one of the costliest in history.

Severe rain storms in the area prior to January 28 caused large amounts of debris to be washed out of the 2,000-square-mile drainage basin surrounding Santa Barbara into the channel and onto the beaches in the area. The free-floating debris became mixed with oil floating ashore, and the debris on shore also became coated with crude oil. The primary oil cleanup effort consisted of spreading straw and other commercial sorbents on the crude oil slicks as they approached the beaches, and then manually recovering the oil-soaked sorbents from shallow water and off the beaches. Thus, the oil-soaked straw and natural debris resulted in a monumental solid-waste-material recovery and disposal problem. The recovery methods are described below(1):

"Beach cleanup was generally accomplished by spreading absorbent straw before and after arrival of the oil, pushing the mixture into piles either by hand or by machine, and loading the accumulation into dump trucks for subsequent inland disposal. The requirement for extensive manual labor made beach cleaning operations extremely slow and costly. Motorized equipment, such as graders, bulldozers, loaders, and straw mulchers, were employ-

---

(1) Swift, W. H., et al, "Review of Santa Barbara Channel Oil Pollution Incident", Report by Battelle-Northwest to Federal Water Pollution Control Administration and U. S. Coast Guard (July 18, 1969). PB-191 712.

ed as much as possible when available. However, many areas were inaccessible to motorized equipment due to lack of access roads or impassibility because of heavy seasonal rains.

"Two types of motorized equipment proved effective during beach cleaning operations: Straw mulchers or spreaders normally used to prevent erosion of highway rights-of-way, and graders with tines welded below the blade for raking. The need for equipment modification or more maneuverable and more efficient motorized rakes to pile the oily straw mixture is indicated."

The mechanical mulchers were capable of broadcasting 8 to 10 tons of straw per hour, and vessels working parallel to the shoreline a few hundred yards off the beach were spreading up to 140 tons of straw per day. In late February, two vessels working near Platform A spread up to 45 tons of straw per day, but this method was ineffectual because no effective mechanical means for recovering the oil-soaked straw from open waters was available.

Estimates of the number of men and the amount of equipment needed for the beach cleanup varied. One source indicated that beach cleanup operations included 550 personnel, 54 water craft, 29 pieces of heavy equipment, 96 trucks, and 7,000 tons of straw(1). As of June 1, 1969, some 9,826 truckloads of debris had been removed for disposal.

In protected harbors, straw was often spread by hand on rainbow slicks, and then recovered manually with rakes and pitchforks along with naturally occurring debris which had become oil-soaked. The men generally worked from punts, roughly 10 feet long by 4 feet wide with 18 inches of freeboard, and loaded debris into open 55-gallon drums. Skirted boom was fairly effective in corralling and concentrating oil/debris in quiet waters. Along rocky shorelines and breakwater rip-rap, oil-soaked straw and debris had to be removed by hand and loaded into containers before the oil could be washed and/or sandblasted off the rocks. This latter operation was extremely costly and time-consuming.

---

(1) Swift, op cit.

Two schemes for recovery of oil-soaked straw and debris were proposed but not attempted during the cleanup. In one proposal, 5,000 feet of gill net were offered by the Bureau of Commercial Fisheries to be dragged through the water to collect oil-soaked material. The other proposed that commercial kelp harvesters be used to recover the oil-soaked straw. The main objection to the kelp harvesters was that their cutting and harvesting mechanisms created so much turbulence in the water that the oil remaining in the water would become emulsified and thus much more difficult to recover than the original slicks.

The removal and disposal of oil-soaked debris from the beaches posed problems in addition to those already mentioned. All the debris found on contaminated beaches was necessarily removed, whether or not it was oil-soaked. Much of the driftwood had to be cut up with power and hand saws before it could be placed in trucks and hauled away for inland disposal. The Union Oil Company estimated that some 30,000 tons of storm debris were removed for disposal(1). Mechanized equipment used in debris handling included bulldozers, skiploaders, cranes, hayblowers, dump trucks, motorized rakes, graders, a sand-sifting machine, forklifts, brush burners, chain saws, fertilizer spreaders, numerous utility vehicles, and trucks. Hand equipment included pitchforks, steel brooms, square-point shovels, rakes, axes, hand saws, rope, and pickaxes(2).

Much of the oil-soaked straw from the beaches had to be mixed with additional straw before it would be accepted at the inland dumping sites to prevent leaching of oil from the disposal site. This meant that some truckloads of straw and debris had to be returned to the cleanup site from the dump for additional straw to be mixed in, a costly extra handling process.

Although most of the oily debris was disposed of in landfills, some attempts were made to burn oil-soaked straw and driftwood on site. Objections to the smoke and odor resulting from open burning caused this method of disposal to be abandoned. Difficulties were encountered in igniting the piles of wet, oil-soaked straw, kelp, and other debris until they

---

(1) Swift, op cit.

(2) Ibid.

were doused with diesel fuel and diesel-powered fans were used to provide good draft. On-site burning of oil-soaked debris has some advantages over landfill dumping (reduced temporary storage and trucking requirements), but some kind of forced-air, high-temperature, portable incinerator would be required to reduce air pollution to acceptable levels.

Selection of landfill sites was a major problem. Several sites were employed, with three receiving the bulk of the oily debris. Two shallow-burial landfill sites received a total of about 40,000 cubic yards, and about 20,000 cubic yards went to a highway construction site. These sites had to be selected and prepared to avoid pollution of nearby areas and water supplies by leaching of oil from the debris. Disposal costs were estimated to be about \$200,000[1].

9. Bay Marchand Spill

On the morning of December 1, 1970, the nearly completed B-21 well on Shell Oil Company's Platform B in the Bay Marchand Block 2 field in the Gulf of Mexico blew out and ignited. Several of the 22 producing wells on the platform also began to burn and to leak crude oil onto the ocean surface. Oil pollution containment procedures were put into effect almost immediately to collect unconsumed oil before it could drift onto Louisiana beaches 8 miles to the north.

Several open-ocean oil-skimming rigs were placed downwind of Platform B, but there was no significant problem with waterborne debris at the offshore oil-recovery sites, and no mechanized debris-handling equipment was used. Several shallow-water oil-skimming rigs were also put into operation and picked up oil which got past the large rigs offshore, but again there was no significant problem with debris.

Commercial sorbents, along with some 22,000 bales of straw, were stockpiled to deploy on oil which came ashore on the beaches, but they were hardly used. It was believed that the natural effects of wind, waves, and currents would cleanse the narrow, shallow, sandy beaches more effectively

---

(1) Swift, op cit.

than would widespread use of straw and sorbents. Cleanup crews patrolled the beaches and scooped up persistent patches of crude oil and shoveled them into containers along with oil-fouled sand and debris such as bottles, plastic cups, cans, paper, and milk cartons. This was, however, a minor part of the cleanup.

10. Chevron Platform Charlie Spill

Chevron Oil Company's Platform Charlie (MP41C) is located in the offshore Gulf of Mexico Main Pass Field, roughly 10 miles east of the Mississippi Delta. On February 10, 1970, the Platform (which is automated) caught fire, and eight of its wells burned until the fires were extinguished March 10. Oil-pollution-response equipment was on the scene less than a week after the fire started, but unconsumed oil was not a major problem until several days before the last of the fires was extinguished. Estimates of the total amount of oil spilled in this incident run from 35,000 to 65,000 barrels[1].

The major oil-recovery efforts were conducted offshore, downwind of the Platform, to intercept the oil slicks and windrows before they could go ashore. The oil-retrieval operations are well detailed in Reference 1.

Due to the winds, the tides, the flushing effect of the Mississippi[2], and the effectiveness of offshore protection and recovery efforts, very little oil actually came ashore. Oil was reported to have hit beaches on Breton Island on March 16, but this was quickly cleaned up by manually spreading and recovering straw, which was later burned. Apparently, no mechanized debris-handling equipment was needed.

---

(1) Alpine Geophysical Associates, Inc., "Oil Pollution Incident, Platform Charlie, Main Pass Block 41 Field, Louisiana", for EPA (May 1971).

(2) Murray, S. P., et al, "Oceanographic Observations and Theoretical Analysis of Oil Slicks During the Chevron Spill, March, 1970", report by Coastal Studies Institute, Louisiana State University (September 30, 1970).

11. San Clemente Spill

On August 20, 1971, a large oil slick was sighted between San Clemente Island and the coast of Southern California. The Coast Guard initiated efforts to identify the source of the spill, and it was eventually established that an estimated 230,000 gallons of Navy distillate fuel was accidentally discharged by the USS Manatee, a Navy oil tanker. The Navy assumed responsibility for the subsequent cleanup efforts, which are reported in Reference 1.

At-sea oil-skimming operations during the San Clemente cleanup were fairly effective. Special skimmers similar to those used in the San Francisco Bay tankers collision were towed alongside a Navy Yard oiler. As in other open-ocean oil-recovery operations, no significant solid debris was encountered. The oil had already been on the water several days when skimming began, however, and as the oil weathered, it formed semi-solid globs 2 to 4 inches in diameter, with the consistency of wet chamois skin, which clogged the hoses of the skimming equipment. When patches of these globs were encountered by the skimmers, they accumulated in the skimmer well and had to be hauled out manually with pitchforks covered with small-gauge wire mesh and then loaded into cardboard boxes. The oil globs, it was found, could also be recovered by changing the vacuum hose connections from the portable Mudhog-type vacuum pump on the YO deck to the YO cargo system. Vacuuming with this system worked well as long as the globs were no more than 2 to 4 inches in diameter.

As the oil weathered and formed larger globs (some up to 3 feet in diameter), more and more of the globs had to be recovered by hand. This resulted in a significant handling and storage problem, as the cardboard boxes became soggy with oil and began to deteriorate. At one point, skimming operations had to be secured to offload 5,000 pounds of oil globs in soggy cardboard boxes. Manual transfer of the oil globs in cardboard boxes from the skimmers to the YO's deck became impossible, even with special wooden

---

(1) Commandant, Eleventh Naval District, "After Action Report, August 1971 San Clemente Oil Spill".

pallets, and a time-consuming light-line transfer system also proved inadequate. Once on board the YO, temporary storage of the oil globs in the deteriorated cardboard boxes and the limited available space caused further difficulties.

To combat the oil-glob problem, a 25-ton Lorain crane, equipped with a specially fabricated 8 by 6 by 2-foot perforated drag bucket, was loaded aboard an LCU along with two standard open-top truckbed-type trash receptacles lined with plastic sheets. With the drag bucket suspended in the water over the side, the LCU maneuvered through the slicks so that the largest globs (now 3 to 6 feet in diameter) entered the bucket. The bucket was then hoisted out of the water and the globs dumped into the containers. This system proved quite effective, particularly where the LCU's maneuverability allowed it to work near rocky or sandy shoreline areas. This method is suited not only to recovery of heavily weathered, congealed oil globs, but also it would be of great value in recovering concentrations of solid debris, such as straw, seaweed, or small pieces of wood.

Beach cleanup of oil and oil-soaked sand and debris was essentially a manual operation, with crews of up to 25 laborers using rakes, shovels, and pitchforks to gather the debris into piles which were then loaded into dump trucks by front-end loaders. In areas inaccessible to heavy equipment, debris was simply loaded into cardboard boxes and carried out to stake trucks by hand. Bamboo or light spring-metal rakes were sufficient for light, small-sized oil deposits; pitchforks were better for seaweed and kelp; grain shovels for heavy oil globs. It was believed that cheaper rakes could have been improvised by tacking expanded-metal screening to heavy dowel or 1 by 2-inch wood, and plastic bags and bushel baskets would have been preferable to cardboard boxes.

The City of San Diego beach cleanup crew has a heavy-duty rake-type bucket mounted on a front-end loader for kelp/seaweed removal which would have saved many man-hours of labor. In addition, ordinary hay rakes, towed by jeep, would have been suitable for gathering oil-soaked debris off the accessible beaches.

12. S. S. Arrow Spill

At 9:30 a.m. on February 4, 1970, the oil tanker Arrow, carrying 108,000 barrels of Bunker C fuel oil, struck Cerberus Rock in Chedabucto Bay, Nova Scotia. During salvage operations on February 12, the ship broke in two with the bow on the rock and the stern sunk in 95 feet of water some 700 yards to the north. The task force to combat the resulting major oil spill was formed on February 20, under the auspices of the Canadian Minister of Transport. By the time the task force was in operation, over half of the 375 miles of coastline around the Bay was fouled with oil, including some 30 miles of tourist and community beaches. Large quantities of oil floated on the surface of the 1,200-square-mile Bay area, and oil was still slowly leaking from the wreck. The oil-pollution cleanup efforts, as well as the very interesting salvage operations, are documented in Reference 1.

During attempts to contain and recover floating oil, the major debris problems were from oil-contaminated seaweed and from large amounts of peat moss which was used as a sorbent. With the water temperature near freezing, pumping of the Bunker C and oil/debris agglomerations was practically out of the question. As a result, oil- and oil/debris-recovery was attempted by using an oleophilic-belt-type skimmer. With the design of the particular unit used, oil and oily debris cling to the belt and are carried up out of the water and dumped into containers (in this case, 55-gallon open-top drums).

As indicated in Reference 1, these oleophilic-belt skimmers worked well in the cleanup effort after receiving some modifications, such as added belt rollers and positive chain drive. Four machines were eventually put into operation--three on 27-foot self-propelled barges, and one on a catamaran. The machines recovered the oil, oil-soaked seaweed, and peat moss at rates up to 45 gallons per minute, although in areas of heavy concentration, manual assistance was required to direct heavy patches of oily debris onto the belts. The full barrels were off-loaded from the skimmer barges

---

(1) Ministry of Transport, Canada, "Report of the Task Force - Operation Oil (Cleanup of the Arrow Oil Spill in Chedabucto Bay)", Volumes I, II, and III (1970).

by crane onto an LCM equipped with cargo-handling gear. This was often the slowest part of the oil/debris-recovery process. The oleophilic-belt skimmers worked best in natural catch basins of oily debris, such as Inhabitants Bay, where 2,000 to 3,000 gallons per day of oily debris were recovered. The development and employment of the skimmers during the Chedabucto Bay cleanup operation are detailed in Volume III of Reference 1.

One interesting innovation, used in inlets and channels around the Bay, was a porous pine-bough boom consisting of chain-link fence strapped between pairs of watertight 45-gallon drums and to a stout steel cable. Conifer boughs were interwoven in the chain-link fence to absorb the oil. These booms worked successfully in up to 6 knots of current and withstood several storms. Observers state that these booms retained oil, oil-soaked debris, and sorbents under severe conditions without parting, and would be well suited for corralling heavy concentrations of debris[2].

Beach cleanup was restricted to the 30 or so miles of recreational beaches and consisted of a variety of methods. On sandy beaches, where patches of oil, oily debris, and peat moss came ashore, crews of workmen raked and shoveled oil-soaked sand and debris into barrels or directly onto trucks for transport to approved dumping sites. In some areas where the potential effects of beach erosion were thought to be minimal, heavy equipment, such as bulldozers and front-end loaders, was used to remove thousands of tons of contaminated beach material.

(1) Ministry of Transport, Canada, op cit, Volume III.

(2) Suplement to Proceedings 1971 Conference on Prevention and Control of Oil Spills, "Question and Answer Discussion, 3:40 p.m., June 17, 1971", sponsored by API, EPA, and USCG (1971), p. 39.

APPENDIX H

SNAG AND DRIFT-RECOVERY OPERATIONS

Appendix H describes snag and drift recovery operations which are currently being performed in the United States.

APPENDIX H

A. SNAG AND DRIFT-RECOVERY OPERATIONS

1. Snag Operations

Snag removal operations are run primarily by the Army Corps of Engineers to rid rivers, streams, and other inland waterways of submerged hazards to navigation. Techniques and equipment for locating and removing snags vary from one region to another depending on the type and size of the obstacle.

a. Norfolk, Virginia

The Corps of Engineers runs a regular snagging operation in the Norfolk-Hampton Roads area which consists of locating and removing obvious snags such as trees, logs, and telephone poles from local navigable waterways. The snagging operation is performed primarily by the derrick boat, Elizabeth, a 104 by 31-foot diesel-powered, shallow-draft vessel equipped with a 50-foot crane. The crane has a lifting capacity of 67,500 pounds at 20 feet and can be equipped with clamshell bucket, log grapple or lifting hook.

b. Savannah, Georgia

A snagging operation was conducted several years ago in the Savannah River which consisted of dragging a submerged cargo net through the bottom mud to recover snags which had been struck by ships. The snags were primarily sunken logs and tree trunks that could not be located from surface disturbances on the water.

During normal snagging operations, debris is placed along the bank in such a way as to minimize the probability of re-entry during high water.

c. Seattle, Washington

The Corps of Engineers operates regular sweeps of coastal harbor areas in the Northwest and in the Lower Columbia River, which involve dragging a submerged cable along the bottom between two boats to snag deadheads (submerged logs that float in a vertical position). The heavier deadheads are hoisted aboard a barge with a cable-equipped crane. Smaller items are hoisted with clamshell buckets.

2. Removal Programs in Navigable Bays, Harbors, Ports, Rivers, and Estuaries

Debris-collection, -removal, and -disposal programs are regularly operated in many parts of the country by such agencies as the Army Corps of Engineers, the Coast Guard, municipal governments, various port authorities, and marine police. The magnitudes of the programs and the types and amounts of equipment involved vary widely depending on the types and quantities of debris encountered, and on various social, political, and economic factors.

a. Northeast

(1) Portland, Maine. There is no regular program of waterborne debris recovery in the Portland area. Items of floating debris which constitute a hazard to navigation are picked up manually by crews of Coast Guard boats on routine patrol from the South Portland base. Items too large to be manhandled are usually taken in tow to the Coast Guard base where they are hauled out of the water by crane.

A debris-cleanup program sponsored by the Portland Harbor Pollution Abatement Committee and staffed by the Neighborhood Youth Corps for several years, consisted of manually retrieving debris from the harbor and depositing it at a burn site at Fort Gorges. Large, heavy pieces had to be towed to the Coast Guard base for outhauling and disposal. The project was run only during the summer months and has not been in operation since 1969.

(2) Boston, Massachusetts. In Boston Harbor, the Corps of Engineers contracts with a local firm for harbor debris-clearance services. This firm operates a boat called the Driftmaster which is equipped with a front-end-loading debris basket. This basket, which is made of expanded metal with 2-inch openings, is 10 feet wide and has a capacity of about 2 cubic yards (Figure H-1). The boat is equipped with a 2-ton hydraulic crane, and larger items can be towed to shore where a 100-ton land-based crane is available. Two 80-ton barge-mounted cranes are also available.

The Driftmaster operates 5 days a week from May to October and, generally, 2 or 3 days a week during the late fall and winter. In addition, the Driftmaster is on call 24 hours a day to pick up specific items of hazardous drift. Roughly 1,000 tons of debris is recovered each year. Daily log sheets indicate that the Driftmaster recovers from 4 to 6 cubic yards of debris each working day, including such items as logs, tires, timbers, boards, camels, scaffolding, fish boxes, fender logs, railroad ties, and sections of damaged piers and small boats. Logs are the most common large items, followed by tires.

According to reference 1, "...the modest program for Boston Harbor does not provide a satisfactory solution to the total debris problem, but it does serve to reduce the hazard to small boats."

(3) New York Harbor. The Army Corps of Engineers in New York City operates one of the most extensive waterborne debris-removal projects in the country. Since the project was instated in 1915, close to 25 million cubic feet of drift and debris have been removed from the Harbor at a cost of well over 10 million dollars. From 1962, the average annual cost of the project was about $522,000 to collect and dispose of approximately 500,000 cubic feet of drift and debris per year.

The floating plant employed for drift removal includes a specially designed craft also called Driftmaster; the lighter, Gorham; the motor tender, Stanwix; the tug, Daly; and several barges. Other elements in the physical plant include piers and adjacent shore area at Caven Point (near

---

(1) Department of the Army, Corps of Engineers, New England Division. "Boston Harbor Debris Study" (July 1973).

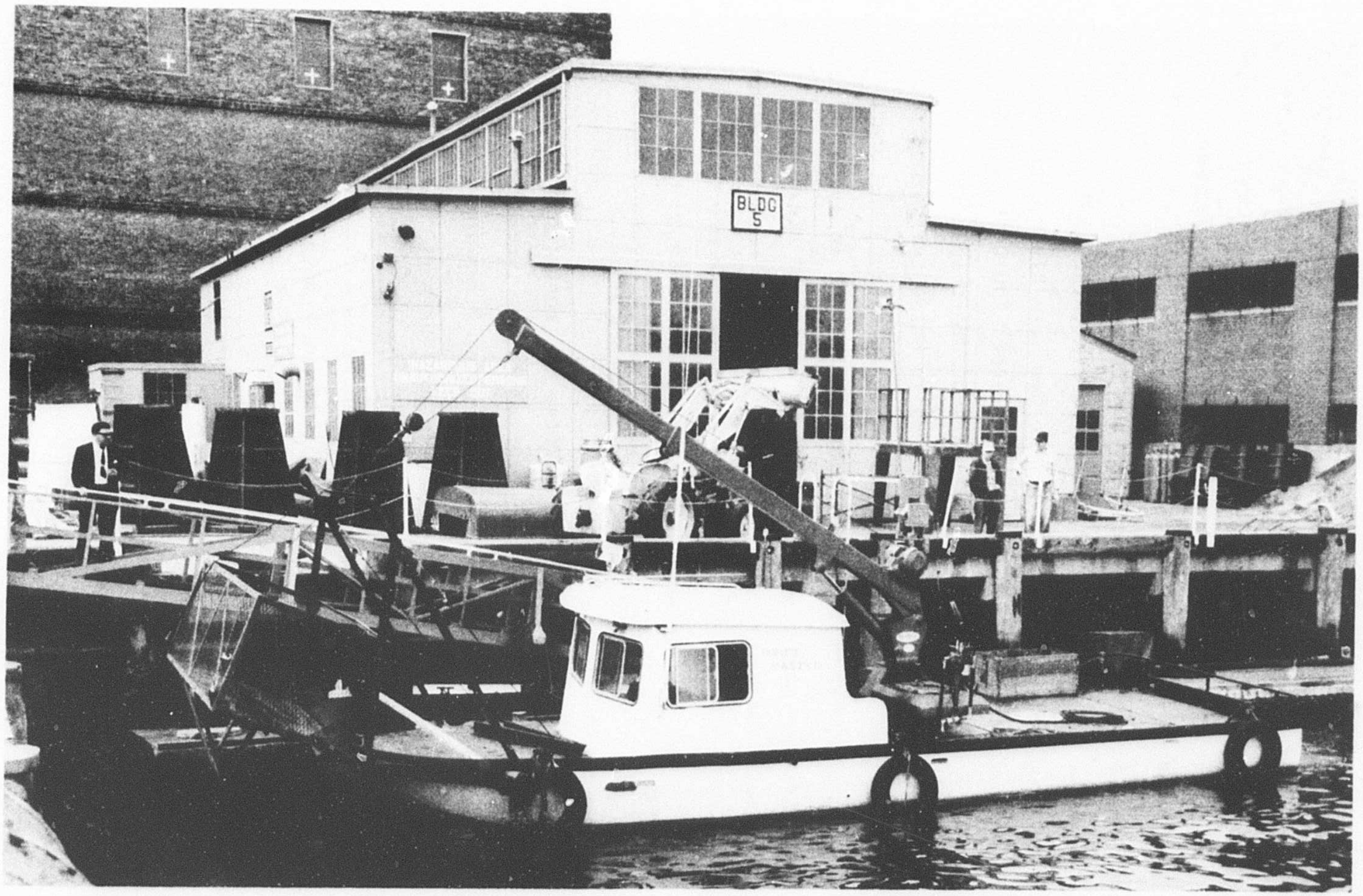


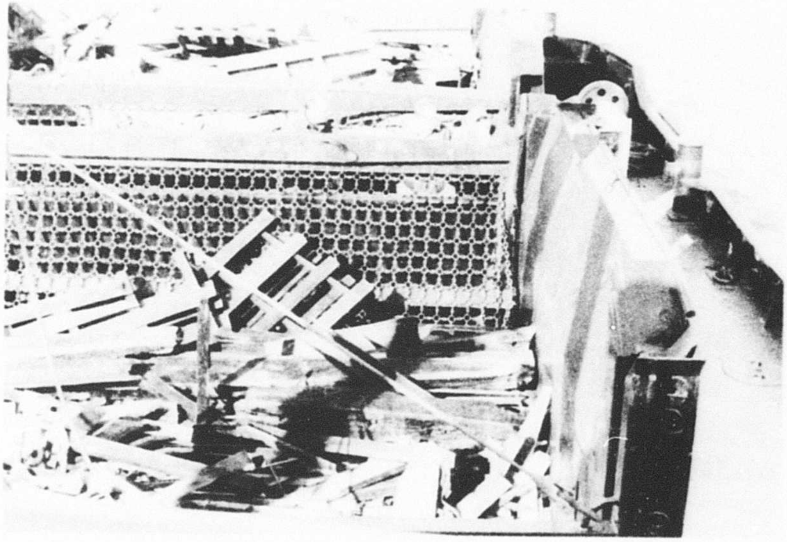
FIGURE H-1. BOSTON HARBOR DEBRIS CLEANUP BOAT, DRIFTMASTER(1)

(1) Army Corps of Engineers, New England Division, Photograph, File No. 177 Boston Harbor (1968).

Jersey City) and a newly installed forced-air incinerator, also at Caven Point. In years past, drift and debris collected by the Corps was placed on incinerator barges and disposed of by open-air burning. To comply with Federal and city air-pollution standards, however, open-air burning has been curtailed, and most collected drift is burned in the specially-designed incinerator at Caven Point.

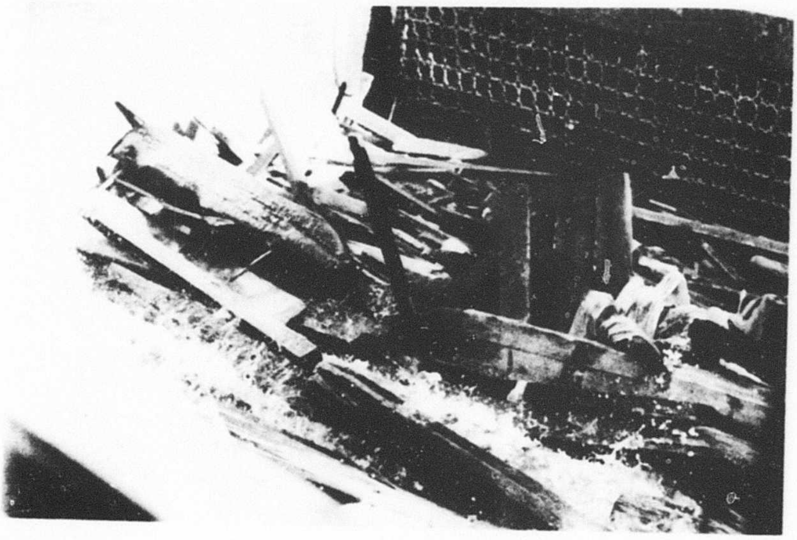
The New York Driftmaster is the first self-propelled vessel designed solely for collection of waterborne drift and debris (Figures H-2 and H-3). The Driftmaster was designed and developed by the New York District Corps of Engineers. It has a catamaran-type hull of welded steel 100 feet long and 36 feet wide, with a molded depth of 10 feet. Normal draft is 6 feet 6 inches. There are no structural members between the two hulls below the waterline, thus providing minimum resistance to propulsion. In operation, the craft moves forward at 6 to 8 knots, and floating debris is caught in a chain-mesh net slung between the hulls. When 7 to 8 tons of debris are trapped in the net, it is raised above the water by a strongback and on-board cable hoist, and a second net is lowered. After the second net becomes full, it too is hoisted free of the water; and the Driftmaster proceeds to Caven Point where the nets are off-loaded by the on-board A-frame crane. The contents of the two nets together, amounting to 1,280 cubic feet, may include some salvageable or nonburnable items. These are sorted out before the remainder (almost entirely wood) is transferred to the incinerator. Salvageable or nonburnable items are sold to commercial firms for salvage or scrap or for landfill projects. Temporary storage space for these items is at a premium (Figures H-4 and H-5).

For drift collection, the lighter, Gorham, tows a catamaran-type collector barge alongside (Figures H-6 and H-7). A chain-mesh net suspended between the hulls of the catamaran barge collects debris as the barge is towed forward. Men stationed on the barge with 16-foot pike-poles direct the flow of debris into the net. When the net is full, the Gorham's 12-ton A-frame derrick raises it out of the water and places it on deck. A second net is put into position on the barge, and drift collection continues. When both nets are full and hoisted on deck, the Gorham proceeds to Caven Point



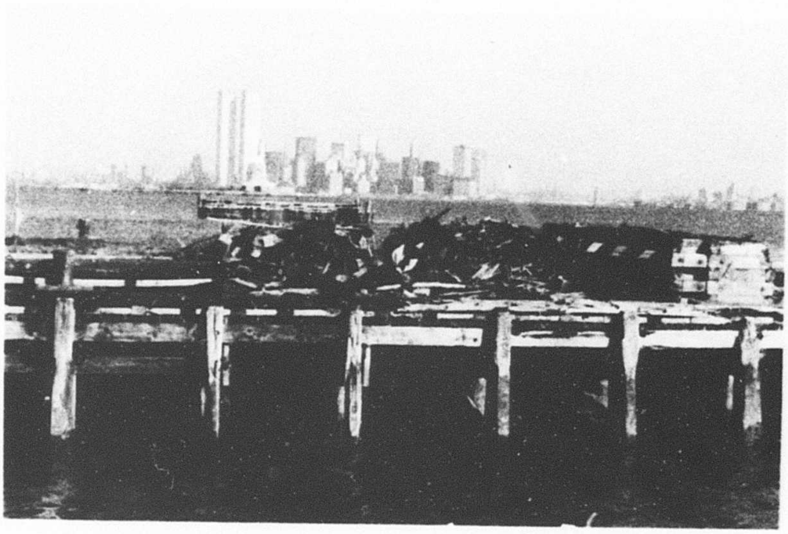
1101-73/H-2

FIGURE H-2. DEBRIS NETS ON NEW YORK DRIFTMASTER



1101-73/H-3

FIGURE H-3. DEBRIS NETS ON NEW YORK DRIFTMASTER

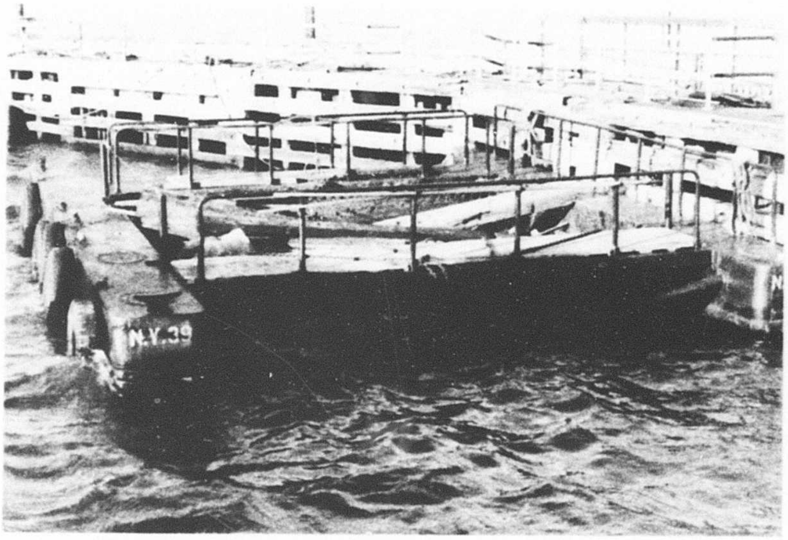


1101-73/H-4

FIGURE H-4. TEMPORARY STORAGE OF DEBRIS AT CAVEN POINT, NEW JERSEY

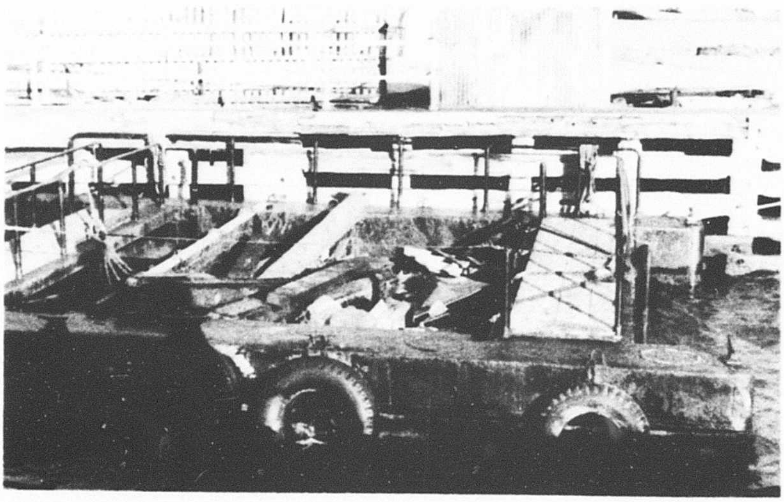
1101-73/H-5

FIGURE H-5. TEMPORARY STORAGE OF DEBRIS ABOARD BARGE AT CAVEN POINT, NEW JERSEY



1101-73/H-6

FIGURE H-6. CATAMARAN DEBRIS BARGE, NEW YORK CORPS OF ENGINEERS



1101-73/H-7

FIGURE H-7. CATAMARAN BARGE WITH FULL DEBRIS NET

for off-loading. Drift collection is a major function of the Gorham, constituting 60 to 70 percent of her duties.

The motor tender, Stanwix, and the diesel tug, Daly, can be used to tow alongside either a catamaran-type barge equipped with one debris net or a drift-collector barge. Both vessels can collect drift in shallow water where the Driftmaster and the Gorham cannot navigate. The Stanwix and the Daly are well equipped to respond to emergency requests from various local authorities and individuals who may on occasion report hazardous floating material that has found its way into boat slips, between piers, near beaches, and other confined areas. Small pieces of debris that can be handled manually are removed from the water and placed on the deck of the barge towed by the tug, Daly. When the barge is fully loaded, it is towed to Caven Point where the debris is off-loaded for eventual disposal.

The incinerator at Caven Point was especially designed for the Corps of Engineers for burning water-soaked debris. The burnable debris consists primarily of wooden items, but such materials as rubber tires, paint, plastics, and paper are also easily consumed. The incinerator, which can handle up to 50 tons of debris per day, is a topless bin measuring 25 by 20 by 17 feet. One of its refractory walls can be lifted for filling. There are no grates and none of the conventional air-pollution-control devices. Loads of debris from the collection vessels are placed in a special dumping pan at dockside and, with the moveable incinerator wall raised out of the way, they are dumped into the fire bin.

Ignition of the water-soaked debris was a problem with open-air burning, but the incinerator has three portable propane-gas igniters which are aimed at the debris through multiple ports in the walls of the fire bin. Often, the debris is sprayed with a jellied petrohydrocarbon fuel booster before the igniters are touched off.

Twelve variable-speed fans force air into the pit from three rows of inlets on each of the three fixed walls. Above the air inlets, near the top of one wall, 19 spray nozzles discharge a fine horizontal curtain of water to keep flyash and other particulate matter from escaping. The 323-gallon-per-minute spray of water hits the opposite wall, where it is collected in runoff galleys for recirculation.

The Corps of Engineers' drift-removal program covers some 1,500 square miles of protected waterways, including some 1,600 miles of waterfront. It is estimated that there are over 2,000 derelict vessels and 330 derelict or abandoned shore structures in this area, which constitute the major sources of waterborne debris in New York Harbor.

Pertinent data on the vessels and physical plant operated by the Corps of Engineers for drift and debris removal and disposal are presented in Table H-1[(1)].

(4) Ports of Philadelphia. Unlike New York Harbor, there is no Federally funded, regular project for the removal of drift and debris from the Delaware River, which flows through the Ports of Philadelphia, Camden (New Jersey), Chester (Pennsylvania), and Wilmington (Delaware). The Army Corps of Engineers removes piles of debris from the shore when notified of an accumulation, providing its crane barge and tug are available at the time. In addition, the Corps prosecutes private owners of dilapidated piers and persons found dumping debris[(2)].

In response to the serious debris problem in the Ports of Philadelphia, the Commonwealth of Pennsylvania operates a debris-collection vessel, the Sheriff, which was converted from a former pusher tug by the Camden Ship Repair Yard at a cost of $50,000. It is 46 feet long and 14 feet wide and is equipped with a starboard bow-mounted hydraulic front-end loader with a steel-framed wire-mesh basket. The loader can rotate 180 degrees to lift debris out of the water and place it on the forward deck. There are no debris containers on board, and temporary storage of debris is limited to the amount (about 6 to 8 tons) that can be placed on deck[(3)].

---

(1) Department of the Army, Corps of Engineers, New York District, "New York Harbor Collection and Removal of Drift", Survey Report on Review of Project (June 1968, revised March 1969 and April 1971).

(2) Delaware River Port Authority, "Keep the Delaware Shipshape", Bridge Plaza, Camden, New Jersey 08101.

(3) Meeting with Mr. James R. Kelly and Mr. William Bennington, of the Delaware River Port Authority, Camden, New Jersey; CDR Lee Tilton, of the Pennsylvania Marine Police, Philadelphia, Pennsylvania; and CDR Mullen and LTJG Steve Connelly, MEP, Captain of the Port, U. S. Coast Guard, Philadelphia, Pennsylvania.

TABLE H-1. DATA ON VESSELS OPERATED BY DEPARTMENT OF ARMY, NEW YORK DISTRICT, CORPS OF ENGINEERS FOR DRIFT COLLECTION UNDER EXISTING PROJECT[1]

Vessel and Type	Driftmaster (catamaran diesel)	Gorham (steam lighter)	Stanwix (motor tender)	Daly (diesel tug)	Two Catamaran Barges	Two Flat Barges	Two incinerator Barges
Date built	1948	1939	1932	1941[a]	1956 1965	1961 1963	1954[b]
Date service began	1949	1940	1935	1948	1957 1965	1961 1963	1962
Dimensions, length, beam, depth, in feet	100x36x10	115x30x12	54x14x7	64x18x8	36x26x6 30x18x5	40x18x3 40x18x3	235x40x12 235x40x12
Horsepower	600	566	220	335	-	-	-
Speed, miles per hour	8.6	12	10	12	-	-	-
Derrick capacity, tons	12.5	12	0.5	3	-	-	-
Crew	8	9-13	4	5	-	-	-
Loaded draft, feet	7	11	6	6	3	1.5	7
Cost, dollars	465,200	220,465	29,604	25,179	11,310 19,925	9,675 9,675	217,506 217,506
Percent of drift collected	50	30	15	5	-	-	-

(1) Army Corps of Engineers, New York District, op cit, p. 11.

(a) Acquired in 1947.

(b) Converted to incinerator barges in 1962.

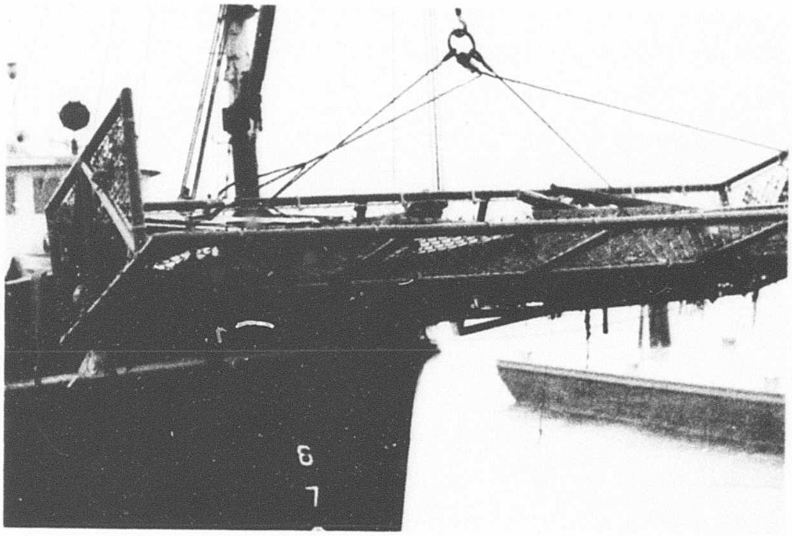
The Sheriff is of double-hulled, welded steel construction and can operate in as little as 3 or 4 feet of water. It can be safely beached for loading or off-loading of debris along the shoreline. Propulsion is by twin 150-horsepower diesel engines, and a crew of three is normally required. The Sheriff often works in conjunction with separate Corps of Engineers barges for additional temporary storage of debris, and it collects an average of 8 to 10 tons of debris per day. The vessel is operated by the Navigation Commission of the Pennsylvania Marine Police, and yearly operating costs run approximately $25,000.

Miscellaneous items of hazardous debris are often picked up or towed to shore by Coast Guard boats on routine patrol. Coast Guard craft on search and rescue or other emergency missions report the position of such debris so it can be picked up by another boat. The debris is reloaded at the Corps of Engineers facility at Fort Miflin. Here, it is stored ashore or on barges for up to 4 months before it can be disposed of by incineration or landfill.

(5) Baltimore. Both the Corps of Engineers and the Maryland Port Authority operate debris-recovery programs in the Baltimore Harbor area. The Corps of Engineers operates a converted 65-foot Army transport boat in regular full-time debris-collection service. The Corps of Engineers' project began in 1948 and cost $888,549 through 1970. The boat is equipped with a steel-framed wire-mesh basket which is approximately 10 feet wide, 5 feet deep, and 2 feet high. This basket is hung over the bow by means of cables attached to an A-frame crane of approximately 5-ton capacity. As the boat moves forward, items of debris are caught in the basket. Once full, the basket is dumped on a barge or dock. The 65-foot boat has no provision for on-board storage but tows a barge alongside when large amounts of debris are encountered. The basket is raised, lowered, and dumped by means of a gasoline-powered winch (Figures H-8 and H-9). The boat carries a crew of four, including the skipper. A private contractor disposes of the debris in approved landfill sites or sells it for firewood[(1)].

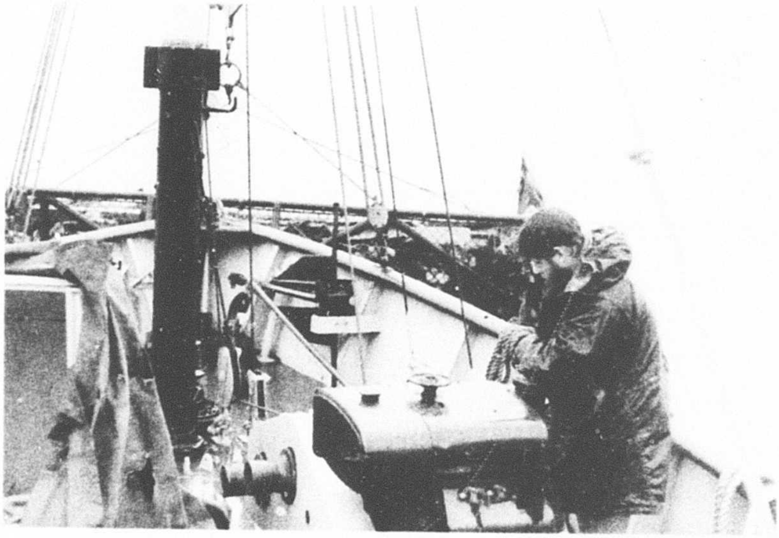
---

(1) Telephone conversation and meeting with Mr. Epstein, Corps of Engineers, Baltimore District (December 1973).



1101-73/H-8

FIGURE H-8. DEBRIS BASKET ON BALTIMORE HARBOR CORPS OF ENGINEERS RECOVERY BOAT



1101-73/H-9

FIGURE H-9. HOISTING DEBRIS BASKET, BALTIMORE HARBOR

The debris boat operated by the Maryland Port Authority in Baltimore Harbor is called the Port Retriever. It is a 7.5-ton craft, about 30 feet long, equipped with a hydraulically actuated front-end-loading wire-mesh basket which scoops up debris as the boat moves forward. When the basket is full, it is lifted clear of the water and dumped onto a waiting debris scow. A second boat, the Port Labor, a 35-foot, 10-ton push-tug workboat, is used primarily for positioning the debris scows near the cleanup site, but it can also be used for carrying and deploying oil-pollution cleanup equipment such as barriers and skimmers. A third Maryland Port Authority vessel is the Port Service, a 38.5-foot modified barge which is used exclusively for the recovery of persistent oil slicks. In the past 5 years, an average of nearly 1,000,000 pounds of debris per year has been recovered from the waters of Baltimore Harbor[1, 2].

(6) Washington, D. C. The Army Corps of Engineers operates a drift-removal program in the Potomac and Anacostia Rivers near Washington, D. C. The program was adopted in 1965, covers a length of 27 miles, and has cost (through 1970) $587,172. Equipment includes two specially built 30-foot workboats, each with a front-end-loading steel-framed expanded-metal basket which is hydraulically actuated for scooping up debris. The debris boats have no provision for on-board storage of collected debris. In the event of heavy debris concentrations, they are usually accompanied by one or more flat barges onto which the debris-laden baskets are dumped. The boats were constructed in 1967 at a cost of $47,100 each. They are single-screw diesel-powered. The debris basket is 8 feet wide, "L"-shaped in cross-section, with 3-1/2-foot "legs", and is mounted on a hydraulic front-end loader capable of lifting and dumping about 2,000 pounds. The debris boats are headquartered at the Corps of Engineers' facility at Eleventh and "O" Streets, S.E., Washington, D. C. Each requires a skipper and one deckhand.

---

(1) Telephone conversation and meeting with Mr. Epstein, op cit.

(2) Port of Baltimore Bulletin (April 1972).

In addition to these two boats, the Corps employs a large barge-mounted hoisting crane with a 3/4-cubic-yard-capacity clamshell bucket which is used to off-load debris from the smaller debris scows that accompany the debris boats. Debris is generally loaded into trucks for further transport by private contractor to a landfill or other disposal site. The Corps of Engineers Project also includes maintenance of debris fences to keep debris from flowing into the tidal pool at the Jefferson Memorial (Figures H-10 and H-11)[1, 2, 3].

(7) Chesapeake Bay. Along the tributaries of the Chesapeake Bay within the State of Maryland, the State Department of Natural Resources, Waterways Improvement Division, has begun a program of debris removal which primarily involves the recovery and disposal of sunken and beached derelict vessels which litter the shoreline. An aerial survey of the State's waterways, included in the project, revealed an estimated 1,000 to 1,200 derelict vessels in the State, mostly along the shores of streams and creeks which lead to Chesapeake Bay.

In 1973, the State appropriated $268,000 for the project. Most of the derelict vessels are small (35- to 40-foot) wooden workboats formerly used by fishermen, crabbers, and clammers; they cost $300 to $500 each to recover and dispose of. Recovery and disposal of large barges costs $10,000 to $20,000. Equipment for the operation includes a 50-foot diesel-powered steel tug; a 24 by 40-foot barge equipped with a hoisting crane and 3/4-cubic-yard clamshell bucket; and a 24 by 60-foot barge for hauling working materials and debris.

This is one of the few current projects which seek to remove sources of debris before they become free-floating. The main purpose of the

---

(1) Telephone conversation and meeting with Mr. Epstein, op cit.

(2) Department of the Army, Corps of Engineers, Baltimore District, "Invitation, Bid, and Award (Supply Contract) for Self-Propelled Drift Collector" (February 3, 1967).

(3) Battelle, Columbus Laboratories, Long Beach Ocean-Engineering Facility, Letter report to Mr. George H. Seufert, Director of Port Maintenance, Long Beach Harbor Department (February 5, 1971).

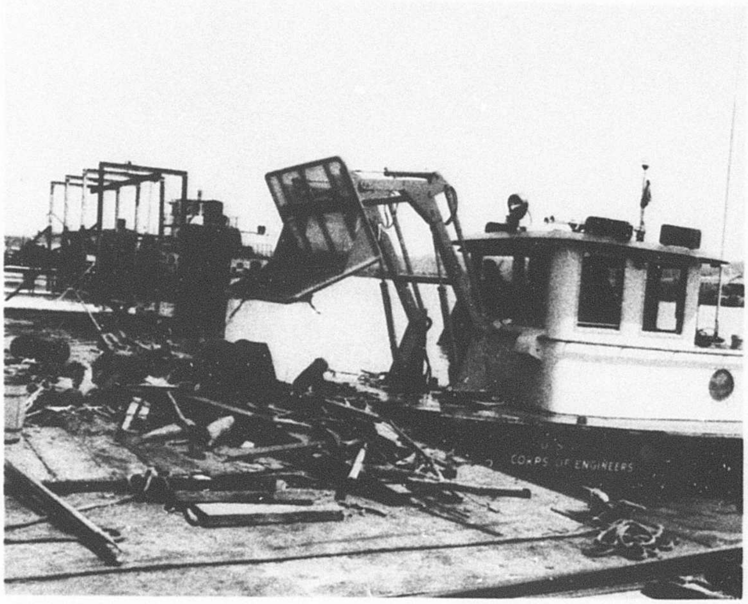


FIGURE H-10. CORPS OF ENGINEERS DEBRIS BOAT, POTOMAC RIVER(1)

(1) Department of the Army, Corps of Engineers, Baltimore District, Photograph No. 6804151 (January 20, 1971).

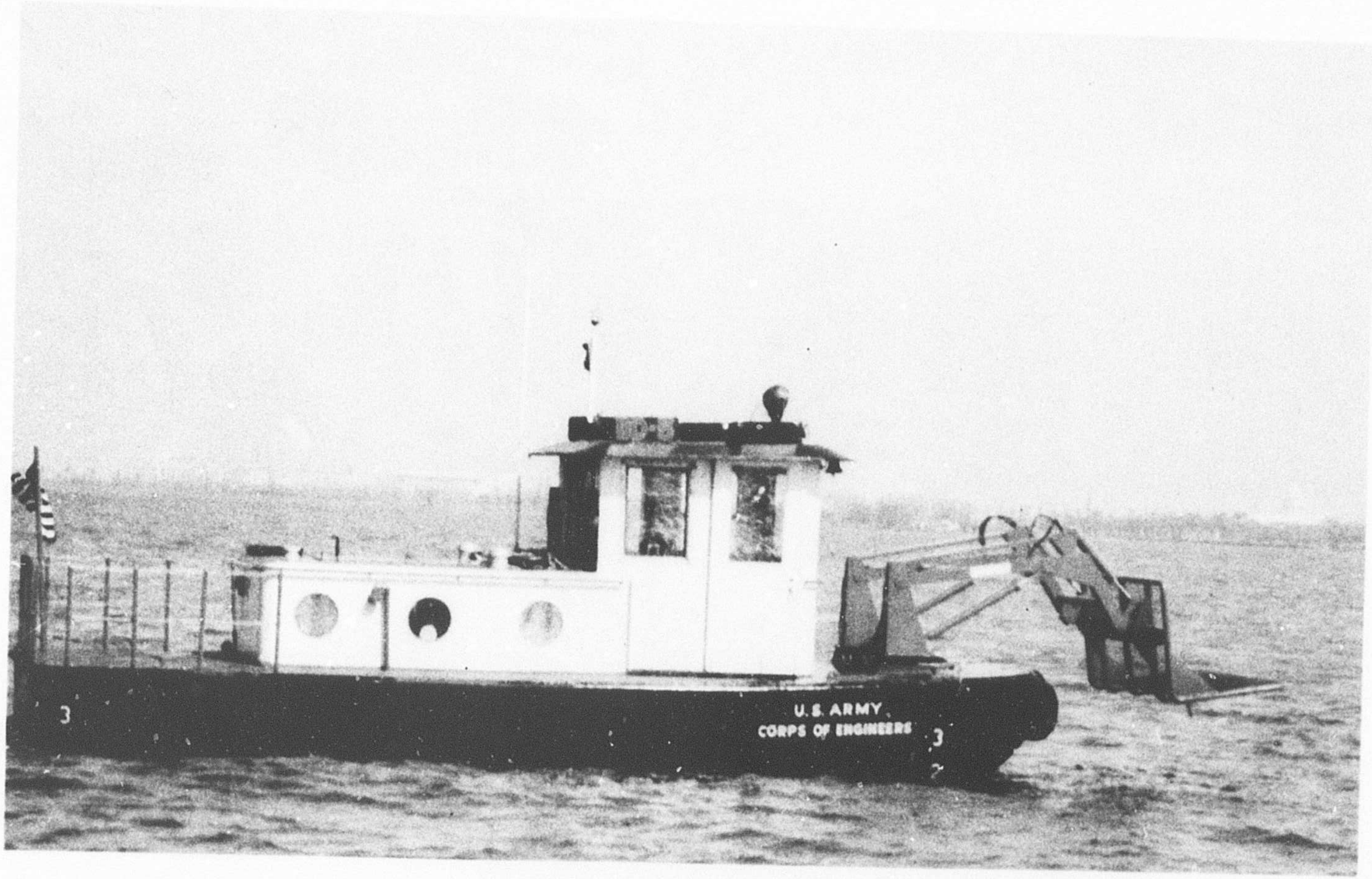


FIGURE H-11. CORPS OF ENGINEERS DEBRIS BOAT, POTOMAC RIVER[1]

(1) Department of the Army, Corps of Engineers, Baltimore District, Photograph No. 6803056 (January 20, 1971).

project has been to improve the appearance of the State's waterways; and in areas where derelict vessels have been removed, especially in residential and recreational areas, the local residents have made an effort to keep the waterways free of other debris and potential debris sources[1].

b. Southeastern Region

(1) Norfolk-Hampton Roads. The Army Corps of Engineers in Norfolk operates four boats in regular debris-pickup service. The principal specifications of the boats are given in Tables H-2, H-3, H-4, and H-5. The general procedure is for the patrol boats to pick up items of debris which they can either handle with their on-board winches or tow to a shore-based crane or to the derrick boat, Elizabeth, which is equipped with a 30-ton crane. Smaller items are generally lifted aboard manually with boat hooks, pike poles, or ice tongs. Corralling the debris with log booms or debris fences has not been attempted.

The present techniques and equipment have proved fairly satisfactory in keeping the Norfolk-Hampton Roads area free of debris that poses a hazard to navigation. The general feeling among Corps of Engineers personnel is that the area is more free of hazardous debris now than in the past 20 years. The debris collected by the Corps is carried or towed to the Craney Island disposal area, where heavy lifting equipment dumps it directly behind the levee for open-air burning. In the past several years, an average of 60,000 to 65,000 cubic feet of drift and debris has been collected and disposed of at an annual cost of roughly $60,000[2, 3].

---

(1) Telephone conversations with Mr. Warren Shelly of the Waterways Improvement Division, Maryland State Department of Natural Resources (November and December 1973).

(2) Telephone conversation and meeting with Mr. Charles Brickner of the Army Corps of Engineers, Norfolk District (October and November 1973).

(3) Department of the Army, Corps of Engineers, Norfolk District, "Collection and Removal of Drift in Norfolk District, Virginia" (January 1969).

TABLE H-2. SPECIFICATIONS OF PATROL BOAT JAMESTOWN[1]

PURPOSE: Used primarily for anti-pollution patrols to prevent and detect obstructive and injurious deposits in waters under jurisdiction of the Supervisor of the Harbor of Hampton Roads. Also used for official inspection trips of the Norfolk Harbor and adjacent waters.

RADIO CALL LETTERS: AEVU

PRINCIPAL CHARACTERISTICS

Length	41 ft. 7 in.
Beam	13 ft. 6 in.
Draft	3 ft. 4 in.
Cruising speed	15 mph
Crew	2

Main propulsion machinery:	
No. engines	2
Type	Diesel
Make	General Motors Detroit Diesel
Model	6V53
Horsepower	216 @ 2800 rpm
Hull	Aluminum
Superstructure	Aluminum

Acquired: Under contract from Grafton Boat Company, Incorporated on 5 January 1973

Small davit with electric winch to handle debris, 2,000 lbs. capacity.

(1) Courtesy of Department of the Army, Corps of Engineers, Norfolk District.

TABLE H-5. SPECIFICATIONS OF PATROL BOAT CRANEY ISLAND[1]

PURPOSE: Used primarily for anti-pollution patrols to prevent and detect obstructive and injurious deposits in waters under jurisdiction of the Supervisor of the Harbor of Hampton Roads. Also used for official inspection trips of the Norfolk Harbor and adjacent waters.

RADIO CALL LETTERS: AEFO

PRINCIPAL CHARACTERISTICS

Length	52 ft. 0 in.	Main propulsion machinery:	
		No. engines	1
Beam	14 ft. 0 in.	Type	Diesel
		Make	General Motors
Draft	4 ft. 6 in.	Horsepower	289 @ 2000 rpm
Cruising speed	12 mph	Hull	Steel
Crew	2	Superstructure	Aluminum
		Ownership	Revolving Fund

Acquired: By purchase from Paasch Marine Service on 1 November 1960.

Davit - Hand Crank

(1) Courtesy of Department of the Army, Corps of Engineers, Norfolk District.

TABLE H-4. SPECIFICATIONS OF WORK BOAT MOBJACK[1]

PURPOSE: Used for general purposes including inspection of fishing structures, drift collection, attending hopper dredges and relief work on anti-pollution patrols.

RADIO CALL LETTERS: AEWI

PRINCIPAL CHARACTERISTICS

Length	65 ft. 6 in.	Main propulsion machinery:	
		No. engines	1
Beam	17 ft. 8 in.	Type	Diesel
		Make	Buda
Draft	7 ft. 0 in.	Horsepower	270 @ 1000 rpm
Cruising speed	10 mph	Hull	Steel
Crew	3	Superstructure	Steel

Acquired: By loan agreement from U. S. Army Aviation and Material Command on 24 June 1963.

(1) Courtesy of Department of the Army, Corps of Engineers, Norfolk District.

TABLE H-5. SPECIFICATIONS OF DERRICKBOAT ELIZABETH[1]

PURPOSE: Used for installing and maintaining fishnet buoys, snagging, bank trimming, drift collection, wreck removal and servicing hopper dredges.

RADIO CALL LETTERS: AEEV

PRINCIPAL CHARACTERISTICS

Length---------- 104 ft. 0 in.

Beam---------- 31 ft. 2 in.

Draft, light, forward---------- 2 ft. 6 in.

Draft, light, aft---------- 3 ft. 8 in.

Draft, loaded, forward---------- 3 ft. 0 in.

Draft, loaded, aft---------- 4 ft. 2 in.

Main propulsion machinery:
- No. engines---------- 2
- Type---------- Diesel
- Make---------- Superior
- Horsepower, per engine---------- 200 @ 1500 rpm

Main hoisting power:
- No. engines---------- 1
- Type---------- Diesel
- Make---------- Cummins
- Horsepower---------- 150 @ 1800 rpm
- Lifting capacity---------- 67,500 lbs. @ 20 ft.
- Boom length---------- 50 ft.

Cruising speed---------- 6 mph

Crew---------- 6

Hull---------- Steel

Superstructure---------- Steel

Ownership---------- Revolving Fund

Acquired: By transfer from Philadelphia Naval Shipyard on 17 August 1960 without reimbursement.

(1) Courtesy of Department of the Army, Corps of Engineer, Norfolk District.

(2) Savannah, Georgia. There is currently no active program for drift and debris removal in Savannah. Patrol boats operated by the Corps of Engineers and the Coast Guard routinely pick up or tow ashore items of debris which pose a hazard to navigation; but there is no specialized debris-handling equipment other than that used in the Corps snagging operation already described[1, 2].

c. West Coast

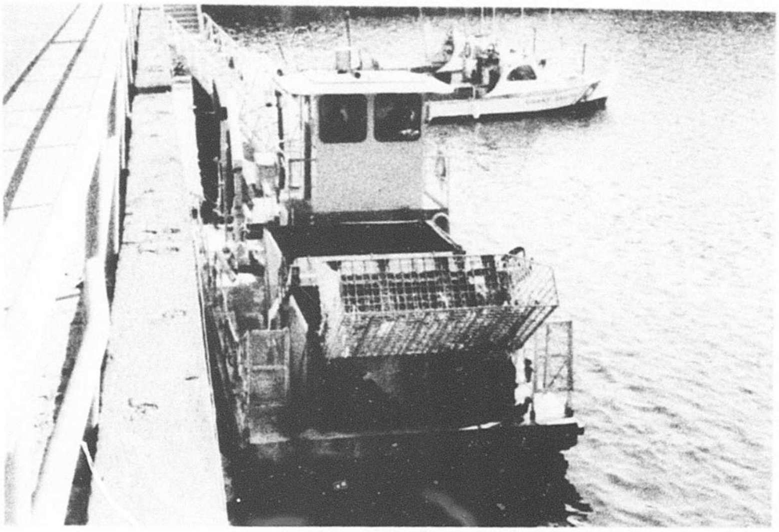
(1) Long Beach Harbor. The Port of Long Beach operates a regular debris pickup and disposal program in the protected water of Long Beach Harbor. A specially designed boat, the Big Dipper, was recently constructed at a cost of $110,000 specifically for the task of retrieving waterborne debris from the Port. The vessel is a 36-foot self-propelled barge with a hydraulic front-end-loading basket. The basket scoops up debris as the boat moves forward and, when full, is raised out of the water and dumped onto the two large steel containers on deck. The basket is constructed of steel reinforcing rod with cyclone fence to trap small pieces of debris (Figures H-12 and H-13). It measures approximately 8 feet wide by 4 feet deep by 3 feet high. The steel debris containers measure approximately 5 by 9 by 6 feet, and contain approximately 10 cubic yards of debris. It generally takes the two-man crew of the Big Dipper 4 to 5 days to fill both containers; then they are off-loaded by a shore-mounted crane. The contents are dumped through a hinged panel on one end (Figure H-14).

The Big Dipper is equipped with a hydraulic telescoping crane mounted on the starboard side aft of the raised pilot house. It has a capacity of 1,100 pounds at a 14-foot extension, or 3,300 pounds at a 4-foot extension. The boom crane is used to hoist aboard items of debris which are too long or bulky for the debris basket. The boat also carries a high-pressure water pump which is used with fire hoses to flush debris from under

---

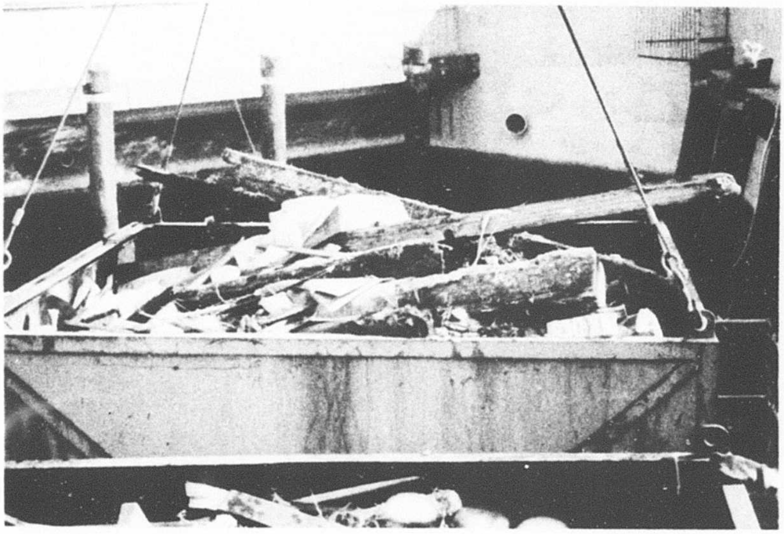
(1) Telephone conversation with Mr. Bob Lane, Georgia Ports Authority, Savannah, Georgia (November 14, 1973).

(2) Telephone conversation with Mr. Oswald of the Army Corps of Engineers, Savannah, Georgia (October 23, 1973).



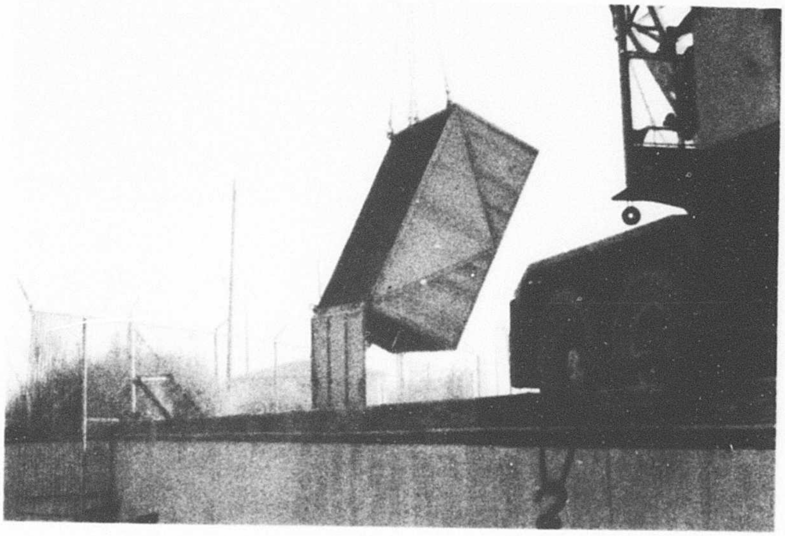
1101-73/H-12

FIGURE H-12. BIG DIPPER, LONG BEACH, CALIFORNIA



1101-73/H-13

FIGURE H-13. DEBRIS CONTAINER READY FOR OFF-LOADING FROM BIG DIPPER



1101-73/H-14

FIGURE H-14. BIG DIPPER DEBRIS CONTAINER AFTER DUMPING

piers and wharves. In addition, pike poles, boat hooks, and nets are kept on board for manhandling debris which cannot be picked up in the basket. A portable chain saw is used for cutting up very large pieces of debris, such as pilings, long logs, and timbers.

Propulsion is provided by a Harbormaster diesel unit with 360 degrees rotation of the lower unit, giving the Big Dipper excellent maneuverability even in confined areas. A separate power plant provides hydraulic power for the debris basket and boom crane. The vessel has been in operation since May 1972; it has a top speed of about 10 knots and can operate in wave heights of 1-1/2 to 2 feet. Although the Big Dipper has some limitations, its operators are generally very satisfied with its performance[1, 2].

(2) Los Angeles Harbor. Debris-cleanup services in the waters of the Port of Los Angeles are provided by three small open boats which were formerly seaplane tenders. Each boat normally carries a crew of two, and debris collection generally consists of hauling items aboard manually or with a 200-pound-capacity hand-cranked hoist. Large items are taken under tow to the port salvage yard where they are stored behind a floating log boom until hoisted ashore by a mobile crane. The boats are also used for other tasks, such as positioning timber camels along wharves for incoming ships, and providing general maintenance work on port facilities. Each boat carries a supply of tools, including a portable chain saw, sledge hammers, rope, nails, bolt cutters, pipe wrenches, and pike poles to enable its crew to perform several kinds of tasks besides debris collection. The boats could be very useful in helping to deploy oil-pollution-response equipment in the event of an oil spill (Figure H-15)[3, 4].

---

(1) Telephone conversation with Mr. Lee Sellers of the Port of Long Beach (October 24, 1973).

(2) Visit aboard the Big Dipper (October 24, 1973).

(3) Telephone conversation with Captain de Santis, Los Angeles Port Warden (October 24, 1973).

(4) Visit aboard Los Angeles Harbor debris boat, Tina Maru (October 26, 1973).

1101-73/H-15

FIGURE H-15. LOS ANGELES HARBOR DEBRIS CLEANUP BOAT

(3) San Francisco Bay. The drift and debris-removal program operated by the Army Corps of Engineers, San Francisco District, is one of the few really large-scale projects of its kind in the country. When the debris situation is most serious, each of the two boats operated by the Corps may pick up as much as 100 tons per day. The two debris-collection boats, Coyote and Raccoon, are modified former Navy YSD vessels. Each is 100 feet long by 30 feet wide and draws 6 feet of water. The boats displace about 215 tons, and each is powered by twin 400-horsepower diesel engines driving 6-foot-diameter propellers which are much sturdier than normal for this size boat, permitting them to operate in heavy debris concentrations without damage.

The boats have specially modified, catamaran-type bows so that a chain-link debris net can be suspended between the sponsons to scoop up debris as the boat moves forward. When one net becomes filled, it is hoisted out of the well and placed on deck by the large on-board crane, and a second net is placed in the well for further debris collection. A total of four nets can be filled on each boat before it must return to the docks in Sausalito to off-load. Collected debris is usually used in sanitary landfill projects.

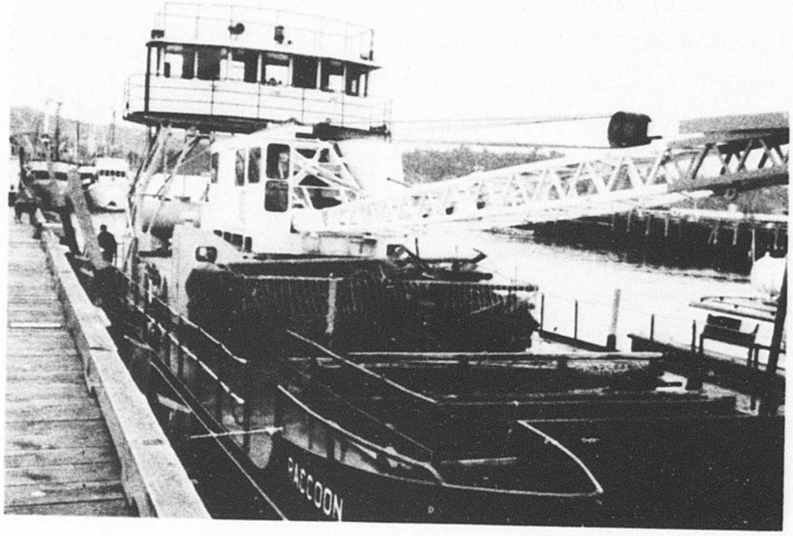
Conditions in the Bay are such that the debris tends to collect in windrows up to several hundred yards long due to the combined effects of wind and tidal currents. Currents vary in parts of the Bay from 2 to 6 knots, and winds often reach 30 knots. The boats are well suited to operate in the relatively protected waters of the Bay but cannot venture to sea since they can safely tolerate wave heights of only 1-1/2 to 2 feet. The Raccoon and Coyote were both instrumental in recovering oil-soaked debris during the Chevron Tankers Bay spill and the Oakland Estuary spill (Figures H-16, H-17, H-18, H-19, and H-20)[1, 2, 3]

---

(1) Telephone conversations with Mr. Bill Angeloni and Mr. Bob Thomas, Army Corps of Engineers, San Francisco District (January 3, 1974 and September 10, 1973, respectively).

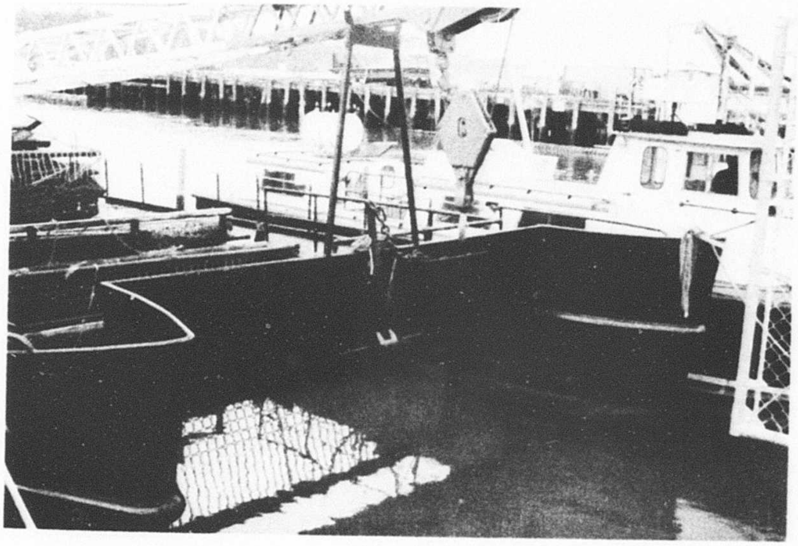
(2) Telephone conversation with Mr. Johnston, Army Corps of Engineers, San Francisco Bay Model (August 16, 1973).

(3) Visit aboard Raccoon with Mr. Bill Angeloni (January 15, 1974).



1101-74/H-16

FIGURE H-16. ARMY CORPS OF ENGINEERS DEBRIS BOAT, RACCOON, SAN FRANCISCO

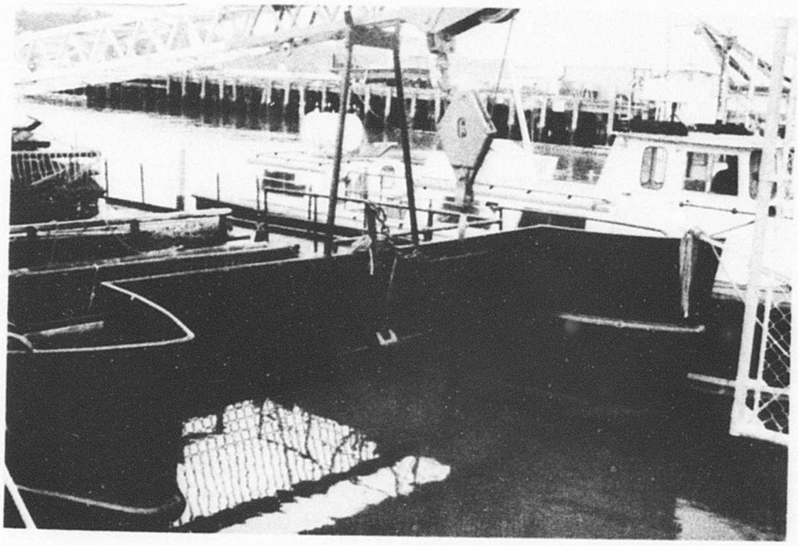


1101-74/H-17

FIGURE H-17. CATAMARAN BOW OF DEBRIS BOAT, RACCOON

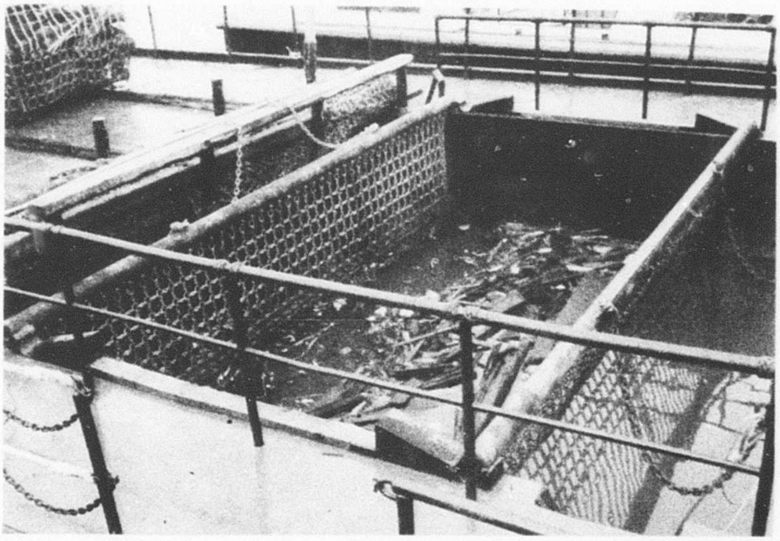
1101-74/H-16

FIGURE H-16. ARMY CORPS OF ENGINEERS DEBRIS BOAT, RACCOON, SAN FRANCISCO



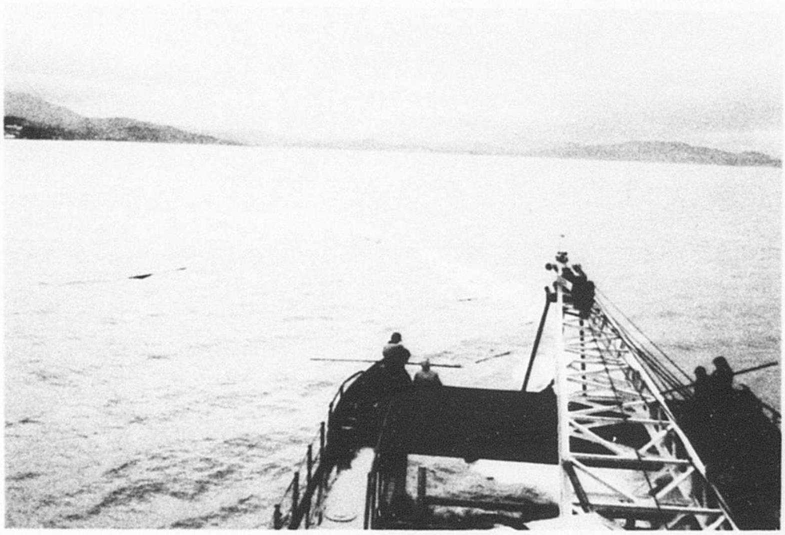
1101-74/H-17

FIGURE H-17. CATAMARAN BOW OF DEBRIS BOAT, RACCOON



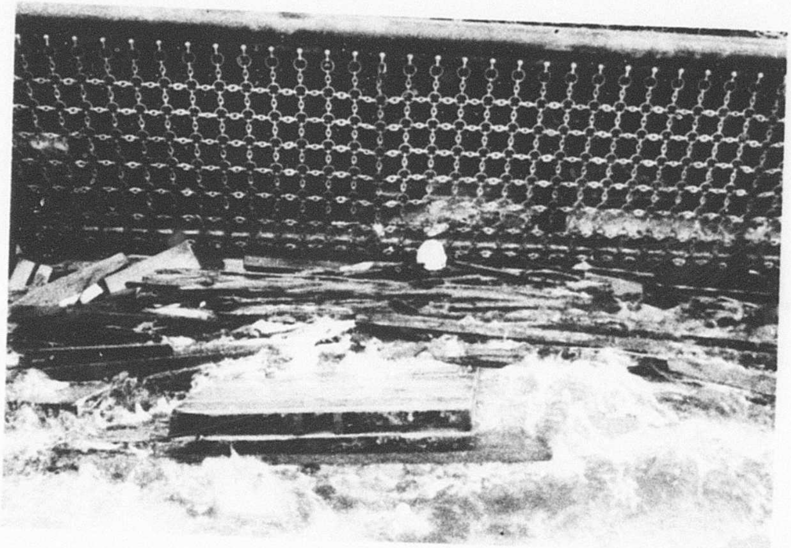
1101-74/H-18

FIGURE H-18. DEBRIS NETS BETWEEN HULL SPONSONS OF RACCOON



1101-74/H-19

FIGURE H-19. CHASING DOWN WINDROWS IN SAN FRANCISCO BAY



1101-74/H-20

FIGURE H-20. DEBRIS COLLECTING IN RACCOON'S DEBRIS NETS

(4) Seattle-Puget Sound Area. A unique vessel involved in regular debris-recovery operations is the W. T. Preston, operated by the Army Corps of Engineers, Seattle District. The Preston is a steam-powered sternwheeler measuring over 163 feet long by 35 feet wide, with a draft of only 3 feet and normal freeboard of 2 to 2-1/2 feet. Built in 1929 for snagging and clearing log jams, her wooden hull was replaced in 1939 with her present steel one. The 18-foot-long by 17-foot-diameter paddle wheel is powered by two 150-horsepower steam engines. Steam is provided by a boiler operating at 180 psi with newly installed (1970) diesel fuel burners. The Preston has a normal cruising speed of 6 to 7 knots in smooth water, 3 to 5 knots in moderately rough water. Her shallow draft, flat bottom, and low freeboard make her unsuitable for operation in the open sea.

The Preston is used most often to clear the Puget Sound area of hazards to navigation such as snags and deadheads. Deadheads lodged in the bottom are located by a light cable drawn along the bottom between two skiffs. Snags and deadheads, as well as other large items of floating drift and debris, are hauled aboard by the Preston's 70-foot boom hoist. A 1-1/4-cubic-yard clamshell bucket and a large wire-mesh dragline bucket are also used on the hoist boom for removing floating debris. In a typical year, the Preston is in operation about 11 months and may pull out 3,500 snags, 150 piles, 40 floats of various sizes, 1,100 cubic yards of trash and debris, and a number of large pieces of drift. The Preston requires a crew of up to 14 and has berthing and messing facilities on board. She has been in successful operation for many years with no time lost due to accidents.

The Seattle District also operates a former Navy YSD, the Puget, in regular snagging and drift-removal work. Large items of drift are removed from the water individually by cable slung from the on-board crane; smaller pieces of debris are corralled by a sweep boom, positioned by small boats, and lifted out by clamshell bucket. Both the Puget and the Preston have some capacity for temporary on-board storage of debris; but where large quantities of debris are expected, separate flat barges are towed to the scene and loaded with debris.

A great deal of the drift and debris recovered in the Puget Sound area is salvageable lumber, but much is also creosoted pilings and logs

which are not suitable for salvage. These items are generally stored on barges or behind log booms for ultimate disposal by private contractors in landfill projects. The total amounts of debris collected by the Corps and disposed of by landfill in Fiscal Years 1972 and 1973 were 2,801 and 2,543 tons, respectively[1, 2, 3].

In addition to the regular operations by the Corps of Engineers, several companies in the Puget Sound area have in the past contracted with members of the logging industry and with the State Department of Natural Resources to retrieve floating stray logs of marketable value and return them to their owners. These log patrols typically employ two small tugboats with a log boom, made of logs secured end-to-end by chain or cable, to corral logs and other floating debris. Sometimes a log boom is run from a convenient point on shore to a tug to divert logs and other debris to a recovery area. Marketable logs are sorted out of the trash and the branded logs sold back to their owners as provided by law. Unbranded logs are sold at auction. The trash and debris collected is usually towed to a suitable landfill project and scooped out by clamshell bucket.

Log-patrol collection operations typically involve one boat with a crew of two working 12 hours per day. Sorting operations usually occupy about 6 hours per day. In 2 months of operation, a typical log patrol recovered 1,200 logs, 200 deadheads, and 2 "sections" of trash--a section being a boomed-off area 70 feet square[4, 5].

---

(1) Latta, R. H., Acting Chief, Operations Division, Army Corps of Engineers, Seattle District, Letter to Long Beach Research Facility (December 7, 1973).

(2) Meeting with Mr. Don Thuring, Army Corps of Engineers, Seattle District (November 28, 1973).

(3) Department of the Army, Corps of Engineers, Seattle District, The Preston Story (April 1971).

(4) Telephone conversation with Mr. Skip Brown, Pacific Towboat Company, Everett, Washington (November 12, 1973).

(5) Telephone conversation with Mr. Dick Hallenger, American Tugboat Company, Everett, Washington (November 13, 1973).

APPENDIX I

DRIFT-RECOVERY PROGRAMS ON RESERVOIRS

Appendix I describes drift-recovery operations on reservoirs. Details of equipment used in these operations are discussed.

APPENDIX I

A. DRIFT-RECOVERY PROGRAMS ON RESERVOIRS

The operations described in this appendix typically employ shore-based, permanently installed equipment and may be part of a flood-control project. They are operated primarily to allow recreational use of the reservoirs. Secondary benefits include protection of hydroelectric power plants, thermal-power-plant cooling-water intakes, and municipal water-supply intakes from damage or clogging due to debris.

1. Ice Harbor Dam

Ice Harbor Dam is located on the Snake River where it joins the Columbia River, about 9 miles upstream from Pasco, Washington. Debris-recovery and -removal facilities there consist of a log-and-chain containment barrier extending out from the left bank of the reservoir, a chain conveyor system, and a log-fork-equipped mobile crane ashore. Floating debris is diverted away from the dam into an area where it is directed by workers to the conveyor and crane. The conveyor snags logs and limbs up to 4 feet in diameter and lifts them up onto the bank. The crane also picks up floating logs and limbs and dumps them on the bank. A bulldozer then pushes the debris into a disposal area. Experience has shown that the crane is the more efficient of the two systems and is preferred by the facility operators. An LCM is also available for tending the log boom, snagging logs which drift past the collection barrier, and miscellaneous debris cleanup.

As much as 50 surface acres of debris are collected and removed in a typical year. (An acre of debris is defined as enough debris to cover one surface acre of the reservoir.) The facility is capable of recovering roughly one acre of debris per day.

In years past, the debris was dozed into a specific disposal area where it was burned; the fire often lasted up to 3 months. Current practice

is to open the disposal area to the public for firewood. This disposal method seems to be working out satisfactorily for all concerned.

Debris that manages to bypass the collection barrier and reach the dam forebay is removed by a trash fork attached to a mobile crane. This debris is hauled by truck to a burn area (Figures I-1, I-2, I-3, and I-4).

Costs in 1969 for debris and drift removal by the methods described above ran approximately $236 per acre, not including costs of burning or fixed plant. Cost of fixed plant was $189,985 to be amortized in 25 years, plus $34,996 to be amortized in 100 years.

2. Grand Coulee Dam

Most large items of floating debris such as logs and log rafts, cribbing, houses, and boats, are collected by a diversionary log-and-chain barrier at the head of Franklin D. Roosevelt Lake. The debris is directed to a shallow, relatively still portion of the Lake where it is contained until the water level in the Lake is allowed to drop, effectively beaching the debris. After nonburnable or heavily polluting burnable items such as car and truck tires are removed, the debris is bulldozed into piles for burning.

In years past, the collected debris covered an area of 35 to 40 acres 10 feet thick, but in recent years this has dropped to 10 to 15 acres 8 to 9 feet thick, owing to the greater number of dams upstream. The debris takes about 1 week to burn.

A new log boom has recently been put in place, which consists of Douglas-fir logs 40 feet long and at least 18 to 20 inches in diameter. Each log has a 4-inch-diameter hole drilled through near each end, and the logs are chained together. The boom is constantly tended by a small tugboat to keep the debris flowing into the disposal area.

FIGURE I-1. DEBRIS HANDLING AT ICE HARBOR DAM (1)

FIGURE I-2. LOG RAKE USED AT ICE HARBOR DAM (1)

(1) Photos courtesy of Mr. Paul Winborg, Army Corps of Engineers, Walla Walla District, Washington.

FIGURE I-3. DEBRIS CONVEYOR AT ICE HARBOR DAM(1)

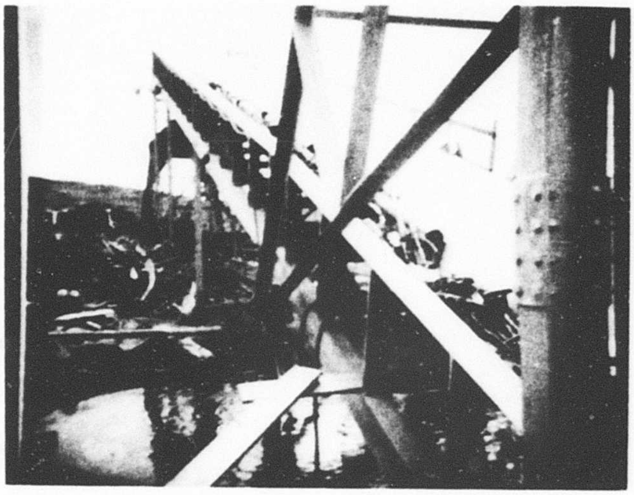


FIGURE I-4. DEBRIS CONVEYOR AT ICE HARBOR DAM(1)

(1) Photos courtesy of Mr. Paul Winborg, op cit.

APPENDIX J

POTENTIALLY USEFUL EQUIPMENT FROM AREAS UNRELATED TO OIL SPILLS

Appendix J contains descriptions of equipment, from areas unrelated to oil spills, that was investigated for possible use with debris in oil spills. Equipment types discussed are logging and lumbering equipment, materials-handling equipment, materials-processing equipment, solid-waste-disposal equipment, agricultural equipment, construction and demolition equipment, dredging equipment, and fishing-industry equipment.

APPENDIX J

A. POTENTIALLY USEFUL EQUIPMENT FROM AREAS UNRELATED TO OIL SPILLS

1. Logging and Lumbering Industry Equipment

In general, logging equipment tends to be extremely large and highly specialized to handle large logs in rugged terrain. Some techniques and equipment developed for firms in the logging industry, however, could be applied to debris-handling situations.

a. Nelson Log Bronc

The Nelson Log Bronc Company of Coos Bay, Oregon, has designed a utility craft for Weyerhaeuser Lumber Company called the Logster, which, its manufacturers claim, will remove debris from inland waterways, skim spilled oil, fight fires, and perform harbor maintenance work. As pictured in Figure J-1, the Logster consists of three modular hull sections with an articulated hydraulic crane and a debris conveyor belt mounted on the central hull module. The standard hydraulic crane has a 25-foot boom, 270-degree rotation, and a lifting capacity of 14,000 pounds at 8 feet extension. Available accessories for the crane include log grapples up to a 42-inch capacity, a clamshell-type wire-mesh debris basket, a submersible saw head, a 7,000-pound-capacity winch, twin-controlled air hoses, and a lineman's bucket for cable-crossing or bridge maintenance. The 48-inch-wide steel screen-type debris conveyor is mounted on the forward end of the center hull section at the throat of a "Y" formed by the outboard sponsons and two extensible arms which direct debris to the conveyor as the craft moves forward at 1 to 3 knots. The conveyor is equipped with 6-inch lands which help to hold debris and guide it up the conveyor and into steel screen baskets for temporary storage and off-loading. An oil skimmer can also be placed in the area between the outboard sponsons.

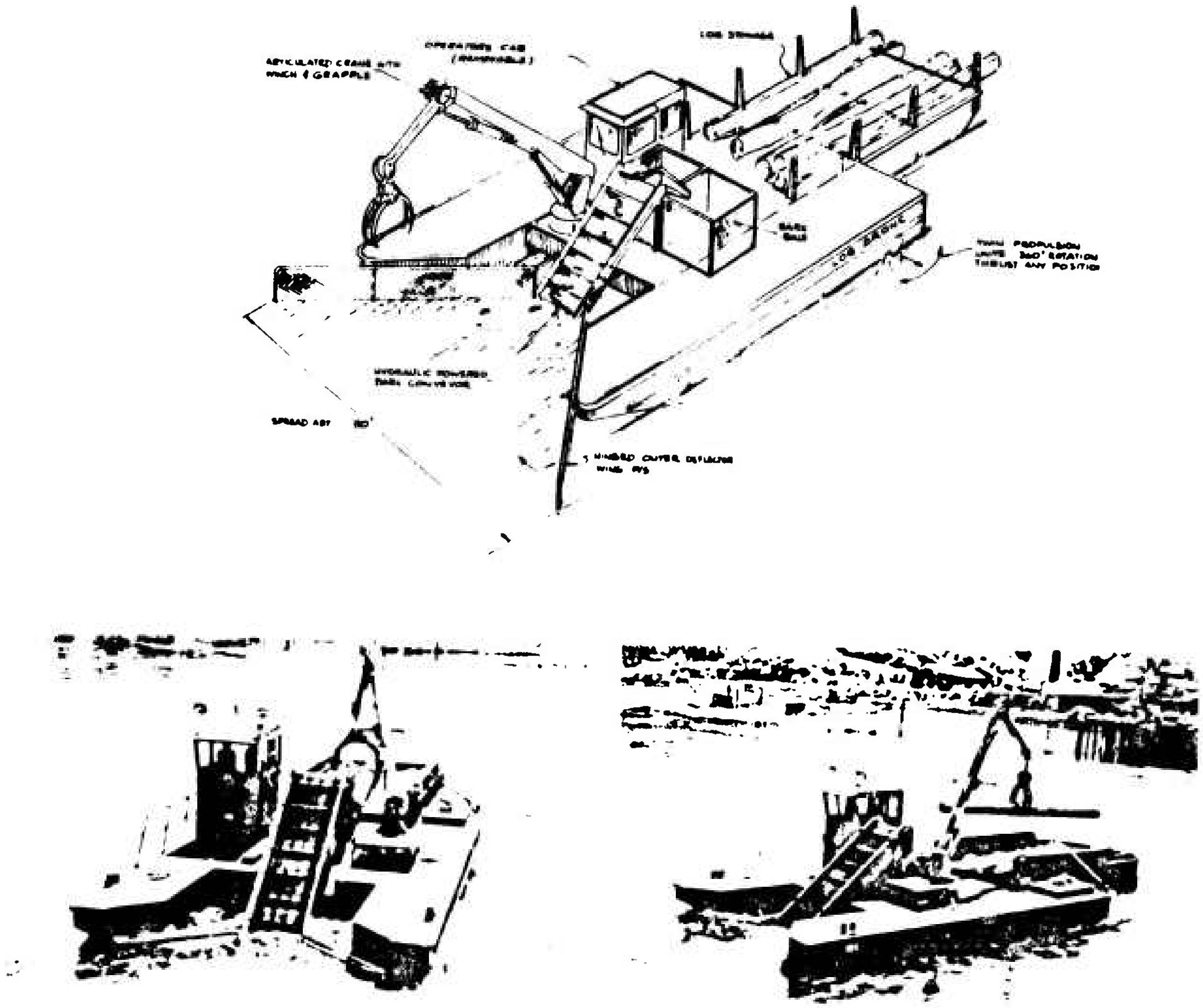


FIGURE J-1. NELSON LOGSTER[1]

(1) Courtesy, Nelson Log Bronc Company, Coos Bay, Oregon.

The Logster is 48 feet long and 22 feet wide overall, but its modular construction allows it to be transported by flatbed truck. The vessel's draft forward is 15 inches and loaded capacity is 75,000 pounds. Twin propulsion units are mounted in the aft end of each sponson and consist of a 100 hp Detroit diesel marine engine driving a Hydro-Drive Model U 360/100 swivel strut drive allowing each of the propellers to be rotated 360 degrees to provide thrust in any direction. The marine engines also supply power to the hydraulic system.

The craft has been in operation since December 1972 and is considered very successful in cleaning up debris from logging operations. Weyerhaeuser has added a crane operator's cab above the pilot house for better visibility and is considering adding larger diesels for increased power and maneuverability.

The Nelson firm is also developing a smaller version of the Logster, 24 feet long by 14 feet wide, for the Simpson Lumber Company. This will be of modular construction and easily knocked down for truck transport on public highways. They are also investigating the possibilities of on-board incinerator units to reduce temporary storage requirements.

Nelson also makes the Nelson Log Bronc in two sizes, as shown in Figure J-2. The Log Bronc is an example of the small, powerful, ruggedly built boats which have been used extensively for log sorting, rafting, and towboat operations in the Pacific Northwest and in other areas of the world. Boats of this small size, maneuverability, and heavy construction would be suitable workboats in heavy concentrations of the largest items of debris in an oil spill.

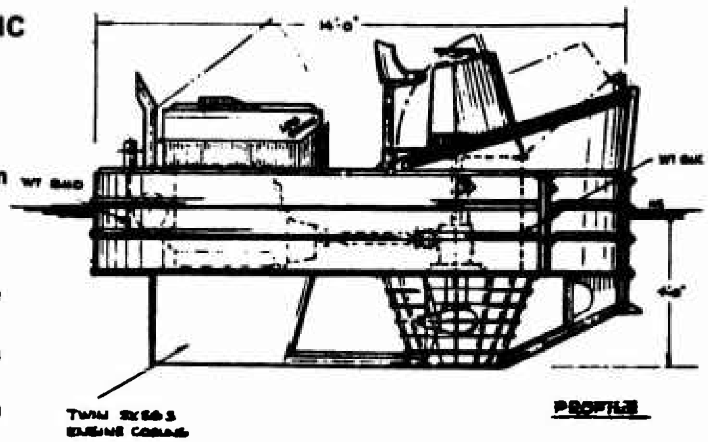
b. Log Grapples

There are a number of different kinds of log and pulpwood grappling devices in use by the logging industry which would be suitable for handling certain kinds of debris. The McGinnes Manufacturing Company, of Houston, Texas, manufactures a line of high-strength-alloy steel buckets and grapples, two of which are shown in Figures J-3 and J-4. Mack Manufacturing, Inc., of Prichard, Alabama, also manufactures a line of grapples, some of which have

MODEL 147 DM

	U.S.	METRIC
LENGTH	14.0 ft.	4.3 m
BEAM	7.0 ft.	2.1 m
DRAFT	3.8 ft.	1.2 m
WEIGHT	8,000 lbs.	3,632 kg
PROPELLER	22 in.	559 mm
FUEL CAPACITY	40 gal.	151 l
POWER	100 h.p.	

STANDARD ENGINE
GM Detroit Diesel Model 4-53 2 Cycle
OPTIONAL ENGINE
Perkins & Chrysler Nissen
MECHANICAL DRIVE UNIT
Hydro-Drive Model 360/100



MODEL 127 DM

	U.S.	METRIC
LENGTH	12.5 ft.	3.8 m
BEAM	7.0 ft.	2.1 m
DRAFT	3.6 ft.	1.1 m
WEIGHT	7,000 lbs.	3,178 kg
PROPELLER	19 in.	482 mm
FUEL CAPACITY	40 gal.	151 l
POWER	75 h.p.	

STANDARD ENGINE
GM Detroit Diesel Model 3-53 2 Cycle
OPTIONAL ENGINE
Perkins & Chrysler Nissen
MECHANICAL DRIVE UNIT
Hydro-Drive Model 360/100

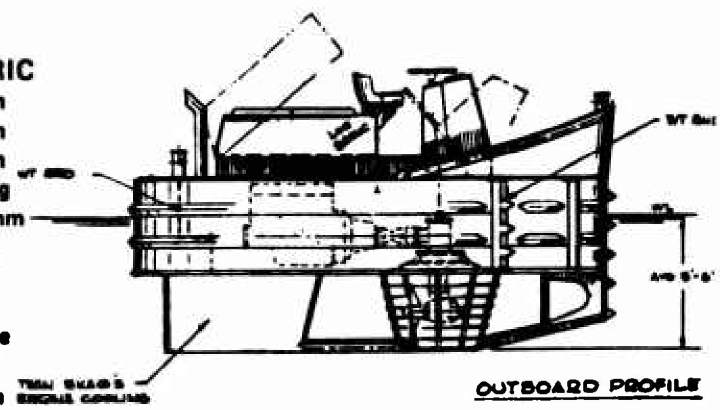


FIGURE J-2. NELSON LOG BRONC[1]

(1) Courtesy, Nelson Log Bronc Company, Coos Bay, Oregon.

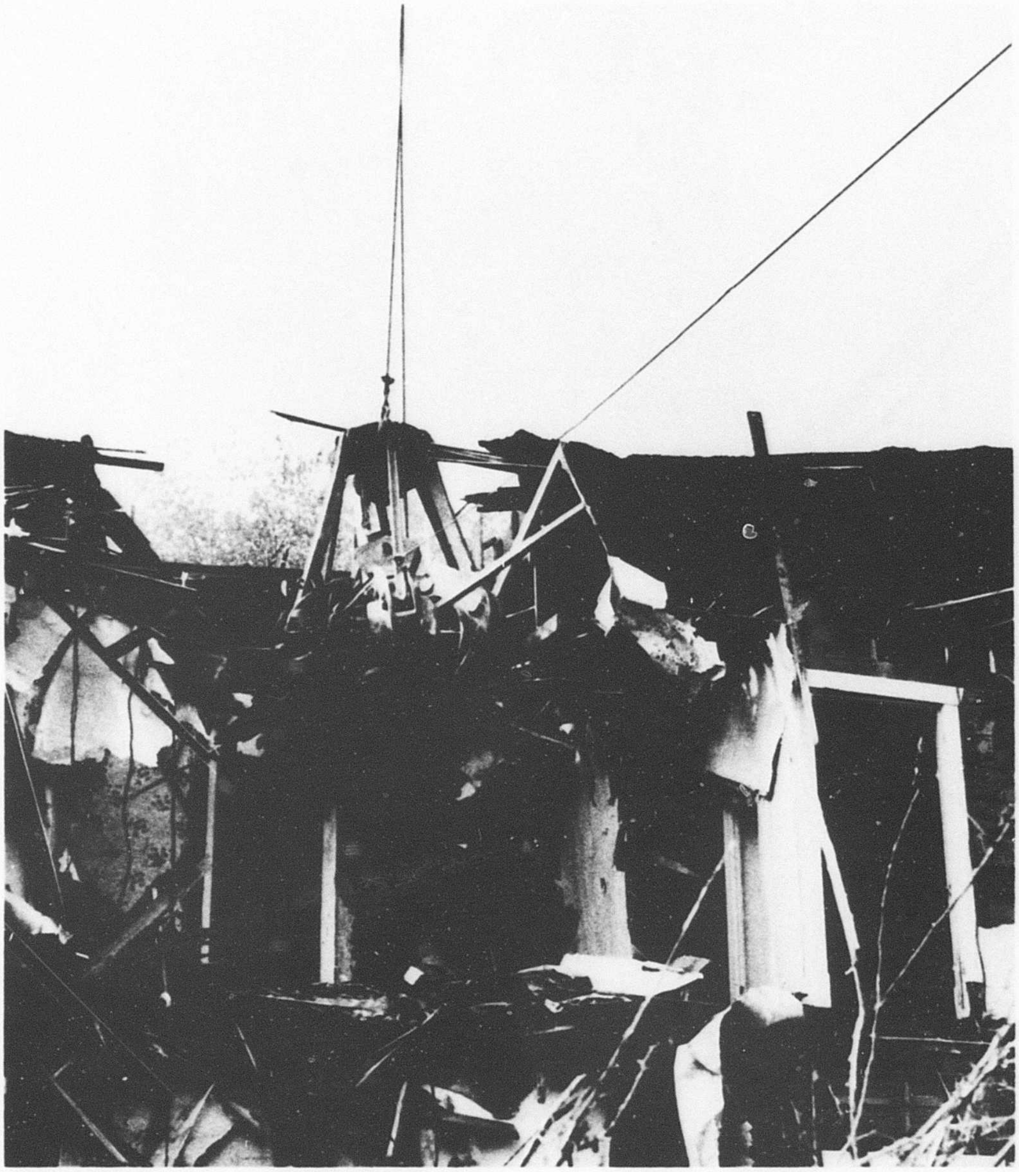


FIGURE J-3. CABLE-OPERATED GRAPPLE(1)

(1) Courtesy, McGinnes Manufacturing Company, Houston, Texas.

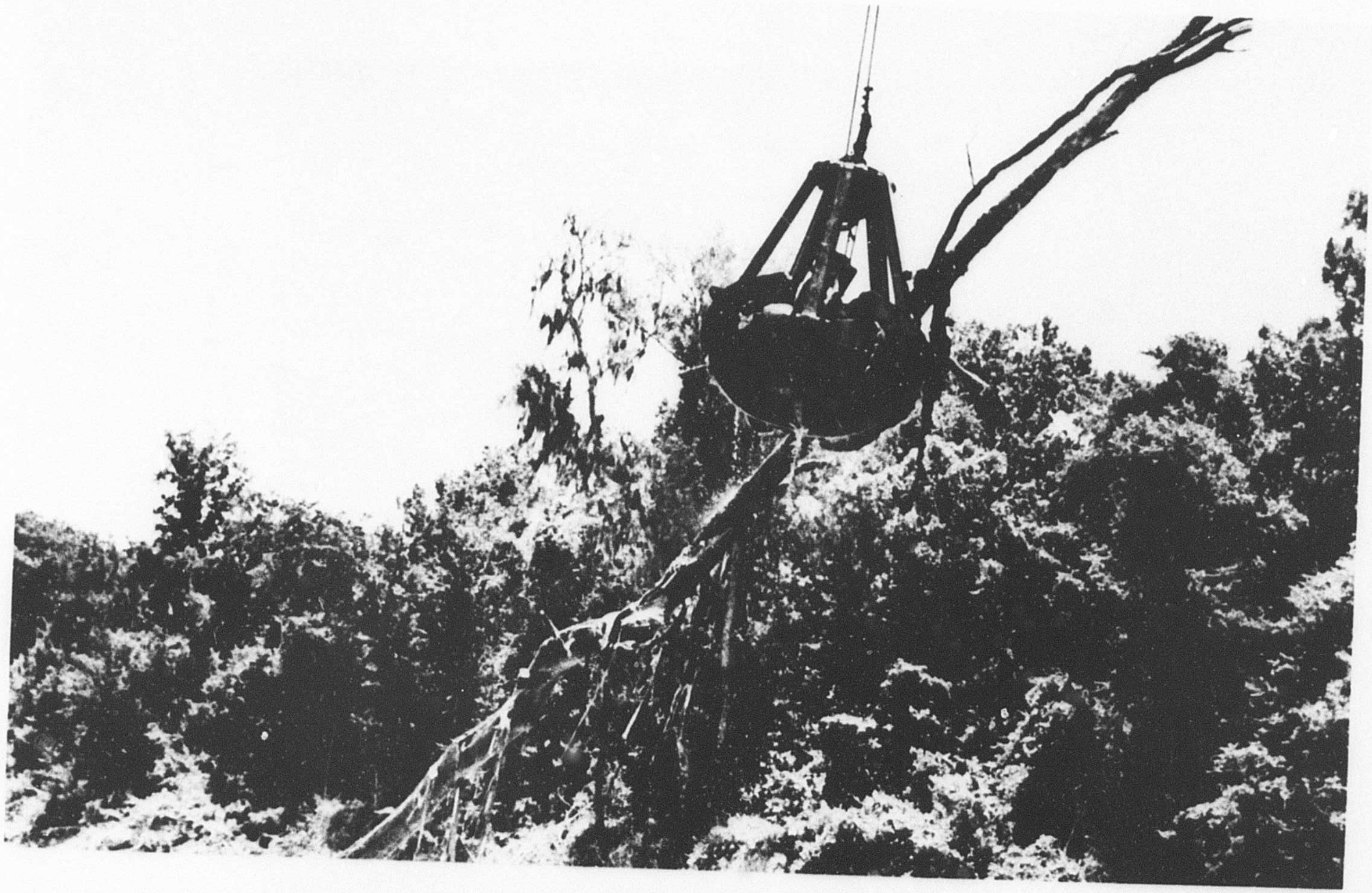


FIGURE J-4. SNAGGING OPERATION USING CABLE-OPERATED GRAPPLE(1)

(1) Courtesy, McGinnes Manufacturing Company, Houston, Texas.

been supplied to the Corps of Engineers for snag and debris removal from waterways and to debris-cleanup operators at dam sites and other locations. The Mack grapples can be furnished for wire-rope, air, or hydraulic operation and include (1) the open-side pulpwood grapple, (2) the 4-tine pulpwood grapple, (3) the 5-tine pulpwood grapple, (4) the standard log grapple, (5) the interlocking log grapple, and (6) the 5-tine scrap and rock grapple.

The advantages of using a log-grapple-type device for clearing debris from an oil spill lie in the fact that a suitable grapple can be selected according to the predominant category of debris which is most likely to be encountered. Grapples are particularly well suited for recovering large- and medium-sized general wood items, discrete lumps and rigid pieces, and some special case items.

Mar Hook and Equipment, Incorporated of Aberdeen, Washington, manufactures a line of automatic releasing hooks and grapples in a range of sizes specifically for the logging industry. These devices would be suitable primarily for handling very large logs and other large general wood items and require a crane with a heavy lifting capacity.

c. Miscellaneous Log-Handling Gear

Both Marathon LeTourneau Company of Longview, Texas, and Raygo-Wagner of Portland, Oregon, supply very large capacity (up to 120,000 pounds) log sorter/stackers to the lumbering industry. These are extremely large vehicles which are used in lumberyards to sort, stack, load, and unload truckloads of large logs. They are very maneuverable, but their use in a debris cleanup would be limited to areas where their weight and size would cause little damage to the environment. Their use would also be limited to those shore areas where debris consists mostly of large wood items and logs. The pictures in Figures J-5 and J-6 are from the manufacturers' sales literature.

Another manufacturer of logging equipment, Washington Iron Works of Seattle, makes a line of specialized equipment including power yarders, mobile logging-slash mulchers, highline spars, and hydraulic log loaders. The yarders are basically very large (300 to 500 horsepower) power winches

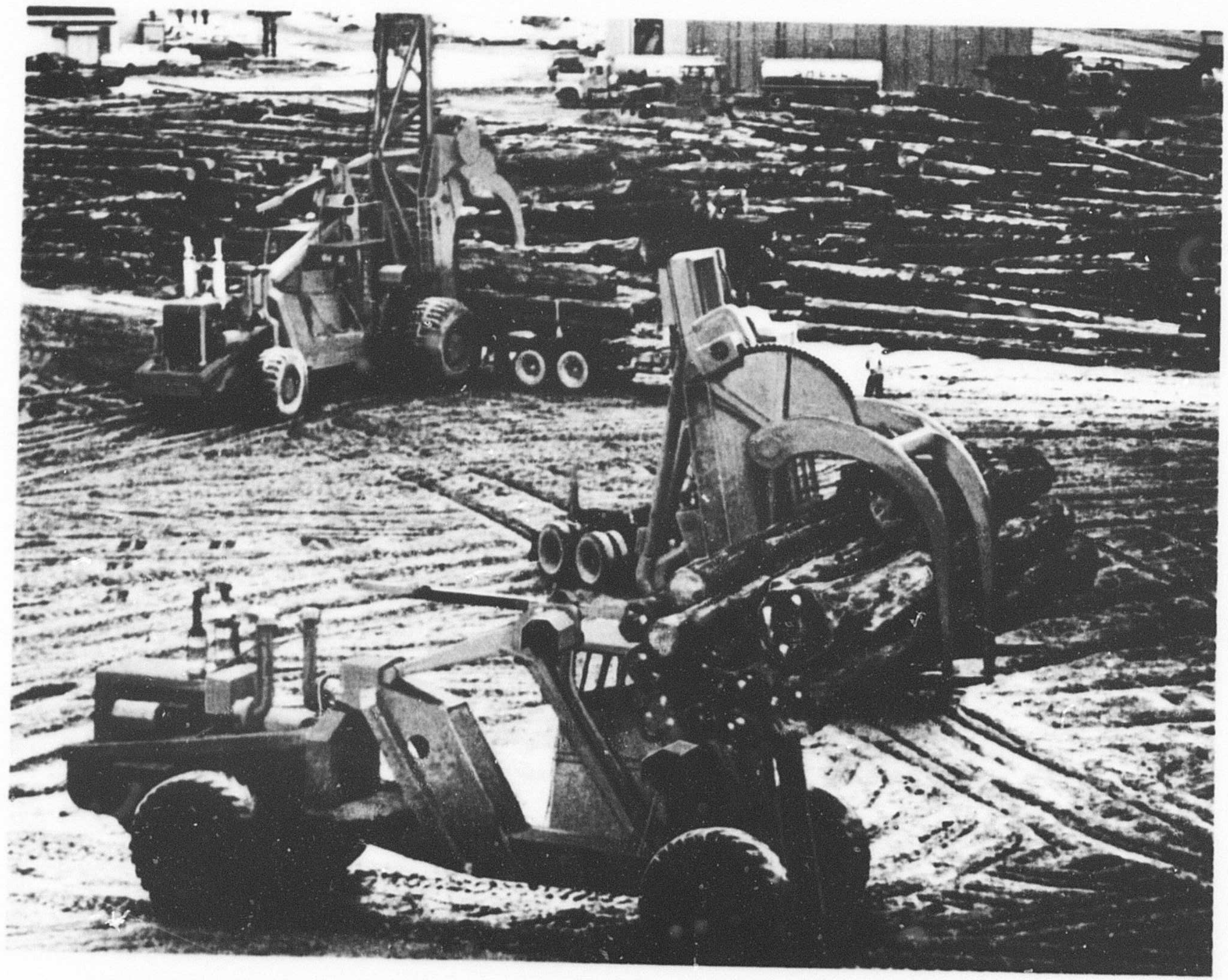


FIGURE J-5. LOG STACKER/LOADER[1]

(1) Courtesy Marathon LeTourneau Company, Longview, Texas.

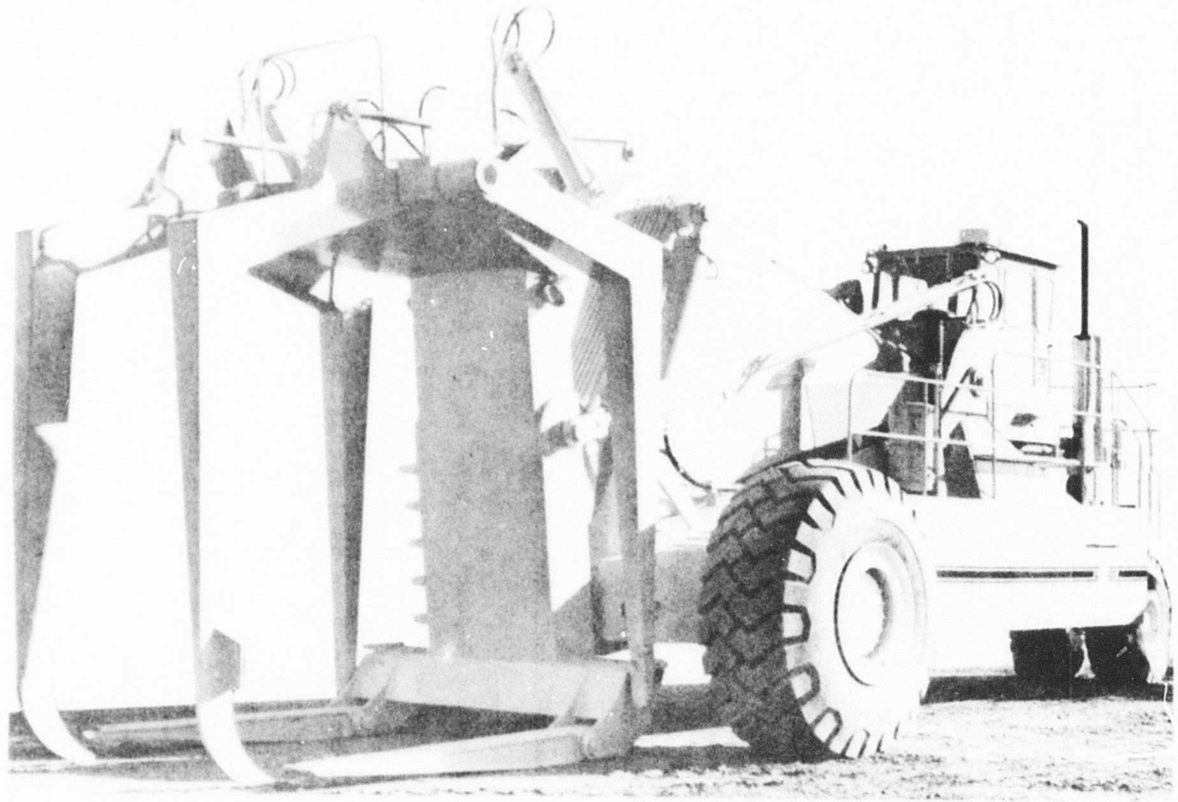


FIGURE J-6. 120,000-POUND-CAPACITY LOG LOADER/STACKER[1]

(1) Courtesy Raygo-Wagner, Portland, Oregon.

which, in conjunction with spars or large cranes, are used to transport logs along cable highlines in mountainous terrain. The techniques involved require semipermanent emplacement of equipment and would have very limited application in a debris-handling operation.

The mobile slash mulcher is a tracked vehicle designed to traverse very rough terrain and, equipped with a boom-mounted rotating cutter, slash small trees, logs, and limbs into small pieces which are more easily biodegraded. Its utilization in debris-handling operations would be very limited, but the rotating-cutter-wheel principle shows promise as a concept for processing certain kinds of oil-soaked debris (Figure J-7).

Washington Iron Works' mobile, self-propelled hydraulic log loaders are specifically designed for handling large logs in rugged terrain. The principles involved in their operation would limit their usefulness to situations where very large items of debris are encountered.

2. Materials-Handling Equipment

A wide variety of equipment is used in the materials handling industry. Some of these have already been used for debris handling in oil spills, while other concepts in technique and equipment look promising for certain situations but have not been used specifically for debris handling. As a rule, materials-handling operations are set up to handle materials with specific characteristics such as size, weight, density, moisture content, etc.; and this would limit the effectiveness of certain kinds of equipment in coping with the very wide variety of material properties found in oil-soaked debris. There are some materials-handling systems, however, which are very versatile in this respect. Also, although many of the concepts discussed are based on permanent installations, they could be adapted to mobile application.

a. Belt and Screen Conveyors

Continuous-moving-belt or screen-type conveyors are widely used in the materials-handling, construction, mining, food-processing, and earth-

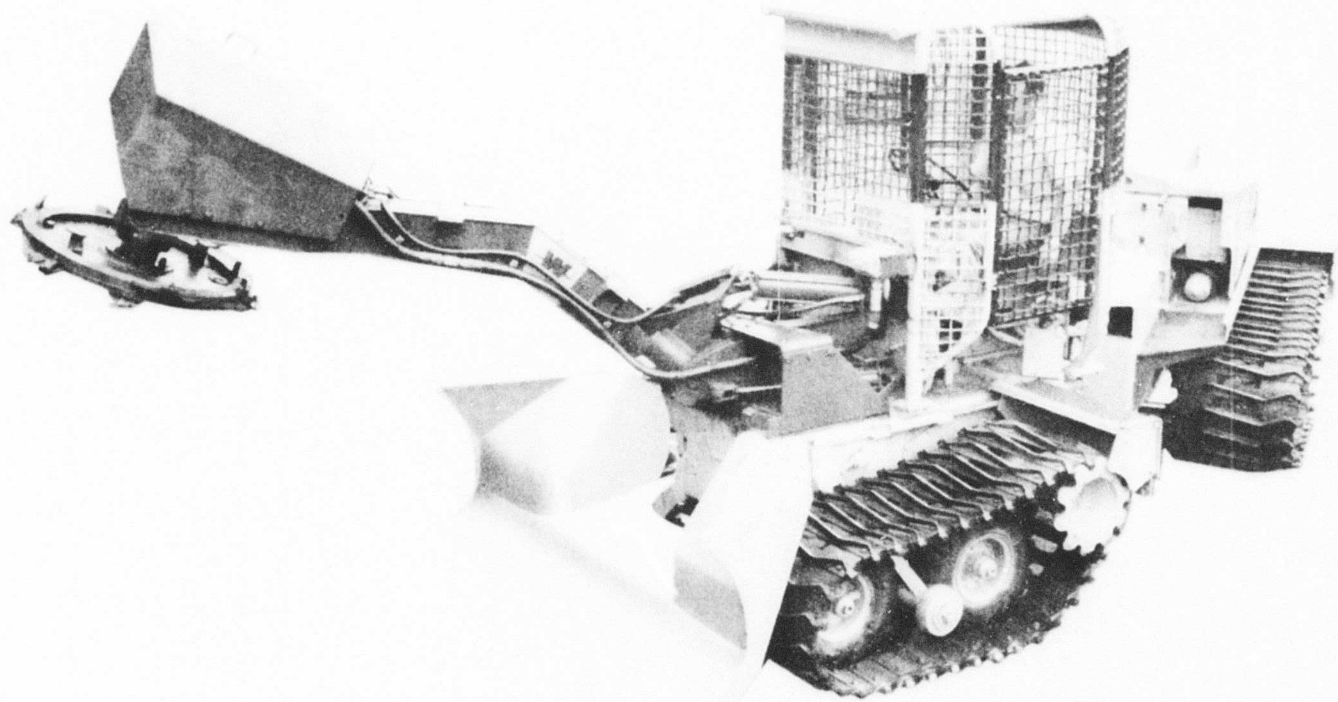


FIGURE J-7. MOBILE LOGGING SLASH MULCHER(1)

(1) Courtesy Washington Iron Works, Seattle, Washington.

moving industries to move large amounts of material at a continuous rate. The conveyors consist of a continuous belt or steel screen which is generally supported at regular intervals by rollers or wheels. The belts may have vertical lands or spikes to keep material from sliding or slipping on the belt surface. Conveyor systems can be of almost any length and, depending on the nature of the belt or screen and the material it is designed to carry, can transport materials in a straight line up and down moderate grades. The advantages of conveyor systems are that they can transport material at high continuous rates; they are basically very simple; and standard components are available from a number of manufacturers. Disadvantages include sensitivity to the size of debris (generally limited to the width of the belt) and the fact that they cannot easily handle certain shapes such as cylinders and spheres.

Some belt-conveyor-type systems have already seen use in debris-recovery operations such as on the Slicklicker and MARCO skimming and debris-recovery vessels. Conveyor-type devices perform the recovery function well in situations where the oil/debris is concentrated and the items of debris are not large or heavy or shaped such that they roll off the belt. Belt- or screen-type conveyor systems would be suitable for transferring most categories of debris from the recovery device to a temporary storage container or a processing device, or from a processing device to a disposal device, etc.

b. Oscillating Conveyors

These are conveyor systems which consist of a rigid trough or screen which is mounted on mechanical, electromechanical, or pneumatic vibrators which impart special orbital motions to the screen or trough. The conveyor is alternately pushed up and forward and then quickly jerked down and backward, thus moving the material on the conveyor forward. Vibrating conveyors are generally used to transport dry, free-flowing, fairly uniform-sized materials such as crushed rock and gravel, grain, coal, etc., at rates up to 150 tons per hour.

Vibrating conveyors are simple, ruggedly built, and come in a variety of standard sizes up to 48 inches wide and capable of handling

materials weighing up to 300 pounds per cubic foot. They could be used to perform transfer or transport functions in a debris-recovery system, although their ability to handle mixtures of oil-soaked debris or large categories might be limited.

c. Screw or Auger-Type Conveyors

This type of conveyor consists of a large, rotating screw- or auger-type impeller mounted in the bottom of a trough or in a tube of nearly the same diameter as the impeller. Material is usually dumped into the trough or fed into the tube at a controlled rate and is pushed along the conveyor by the screw action of the impeller. Conveyors of this type are used to move bulk materials such as grains, fertilizer, dry chemicals, coal, crushed rock, etc., which are generally free-flowing and of a fairly uniform particle size. They are available in a number of different sizes and impeller configurations from various manufacturers. They are relatively unaffected by the moisture content of materials, and they could be used to transfer or transport oil-soaked debris of any category as long as the largest dimension did not exceed the radius of the tube or the pitch of the screw.

d. Dragline Conveyors

This type of conveyor consists of a trough (which can be covered or uncovered) or tube in which a series of equally spaced plates of roughly the same cross-sectional shape as the trough or tube are attached to a continuous chain or cable running the length of the conveyor. The plates, which are perpendicular to the direction of travel, are dragged through the trough and thus force the material to move. These conveyors are used in basically the same applications as screw or auger-types and also come in a wide variety of shapes and sizes. They are relatively unaffected by moisture content of the material to be handled, and could be used to transfer or transport any category of oil-soaked debris where the largest dimension of the debris did not exceed trough width, height, or plate spacing.

e. Vibrating Screens

Vibrating or oscillating screens are used in materials-handling applications for such things as parts sorting, dewatering in food processing, separating solids from liquids, sizing and scalping in the mining industry, and shaking sand from castings in foundries. The screens are manufactured in a variety of styles and capacities, but they are all basically flat, perforated screens or gratings mounted on a vibrating or oscillating mechanism. Their usefulness in recovery, transfer, or transport of oil-soaked debris is doubtful, but they could be used in a processing function to sort out sizes of debris, reclaim useful items recovered in the debris-cleanup operation, rinse oil from debris to facilitate disposal or reclamation, wash oil from reusable oil sorbents, etc.

f. Material Containers

In addition to standard trash containers described elsewhere in this report, there are several kinds of containers which have seen use in the materials-handling industry which could be used in a debris-handling system. One type of container is the folding or collapsible steel-framed wire-mesh container. These are available from several manufacturers in a variety of standard sizes capable of containing solid debris categories in small to medium size classes. They would not be particularly suited to containing amorphous materials or very small (less than about 2-inch) items, but they could be lined with plastic sheet to handle these. Their biggest advantage is that they can be collapsed for easy transport to the debris-recovery site, then assembled for use in temporary storage, transfer, and transport functions. They weigh less than standard trash containers, and can be handled by standard fork-lift trucks or hoisted by crane.

Another kind of container which could be used for temporary storage, transfer, and transport functions is the self-dumping hopper. They are basically open-topped containers which are constructed so that, when loaded, they will automatically tip forward and dump their contents when a safety catch is released. These are also available commercially in a number of sizes capable of handling all but the largest categories of debris.

Four-sided hoppers are available in capacities up to 5 cubic yards and widths to 106 inches, or they can be ordered with open sides for longer items. They can be mounted on skids for handling by standard fork-lift trucks or on their own casters for moving by hand or small truck or tractor. Most containers used in the handling, transport, or storage of bulk materials are designed specifically for the kind of material they are to contain, whether it be a liquid such as paint, petroleum products, chemicals, etc.; or solids such as dry chemicals, salt, grains, sand, etc. As a result, they are generally not suitable for handling the wide variety of sizes and shapes which make up oil-soaked debris. If the debris-handling system were to include a grinding or mulching function to reduce the size of debris to small, uniform particles, then bulk-materials-handling containers could be used more effectively.

3. Materials-Processing Equipment

The concept of processing, in the context of this report, refers to anything which can be done to recovered debris to alter its characteristics in order to (1) make it easier to handle, (2) make it more convenient to store temporarily, or (3) make it easier to dispose of. The materials processing equipment discussed in this subsection consists of machinery which is designed to reduce the size of the various categories of debris and includes grinders, mulchers, shredders, clippers, and hammermills. The machinery is divided into three separate subcategories.

a. Small

These machines are generally used in yard cleanup and gardening work to chop up, shred, or grind typical gardening debris such as leaves, twigs, small sticks, and branches, etc. They are self-powered and easily portable so that they could be placed on a barge or medium-sized workboat. Most of these devices could be used in situations where the debris consists of mostly small categories such as straw, twigs, seaweed, etc. The principles of operation of the small machine are described in an article on pages

116-119 of the November 1973, Popular Science magazine, by E. F. Lindsley, entitled "Chippers and Shredders Cut Your Yard Junk Down to Size". The machines are of three basic types--hammermill-type grinder-composters, shredder-baggers, and dippers. They range in size from 2 to 8 horsepower and in price from $135 to $585.

b. Medium

These machines are commonly used by professional tree trimmers, power company line-maintenance workers, and municipal maintenance workers to pulverize tree limbs, large branches, and trunks of small trees which have been cleared from power-line rights-of-way, city streets, construction sites, etc. They are often mounted on a separate trailer towed behind a dump truck so that limbs and branches are fed in from behind and the wood chips are blown out the front into the truck bed. They generally consist of a high-speed rotary steel cutting or chipping wheel capable of mulching tree limbs up to 8 inches in diameter. The wood chips produced are usually on the order of 1 to 2 inches in diameter. These machines are readily available in most metropolitan areas and can easily be placed on large barges to process nearly all categories of debris except the very large sizes. Difficult items such as steel drums, large nails and spikes in wood, steel cable, etc., cannot be mulched by these grinders.

c. Large

The large materials processing machines are found in the scrap-steel, sewage-treatment, and solid-waste-disposal industries. They are generally very large, permanently installed, hammermill-type shredder machines, some capable of shredding heavy-gauge sheet steel, automobile tires, demolition lumber, and discarded appliances at rates up to 50 tons per hour. The photographs in Figures J-8, J-9, and J-10 show debris entering the shredder and the product coming out. The drawings in Figures J-11 and J-12 show the principle of the large hammermill-type shredder with a metal trap for catching dense, noncrushable metal items such as large nuts

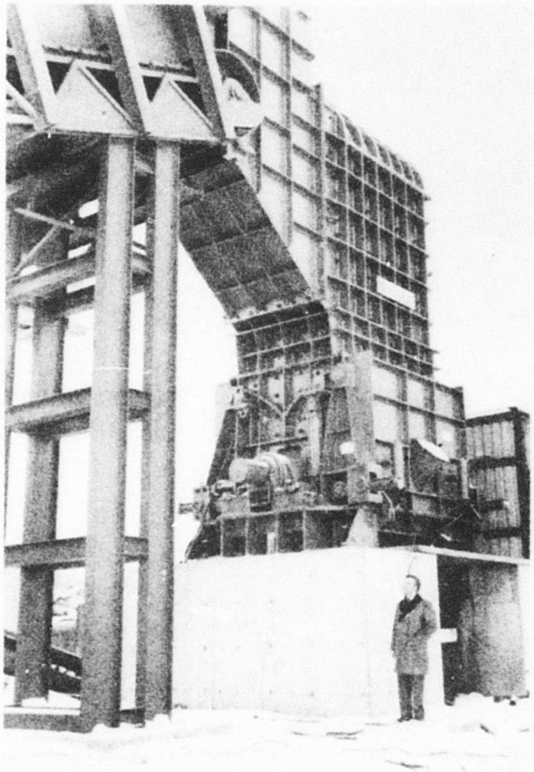


FIGURE J-8. TYPICAL LARGE SHREDDER/MULCHER INSTALLATION (1)

(1) Courtesy Williams Patent Crusher and Pulverizer Co., St. Louis, Missouri.

FIGURE J-9. DEBRIS BEING FED IN SHREDDER/MULCHER (1)

FIGURE J-10. SHREDDED SOLID WASTE AFTER PROCESSING BY LARGE SHREDDER/MULCHER

(1) Courtesy Williams Patent Crusher and Pulverizer Co., St. Louis, Missouri.

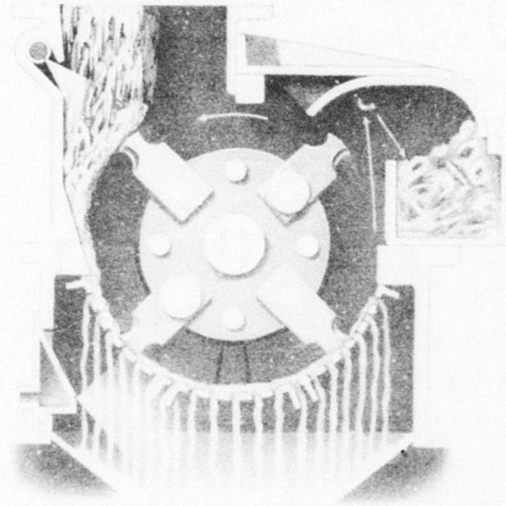


FIGURE J-11. CUTAWAY VIEW SHOWING HOW SHREDDING IS ACCOMPLISHED (1)

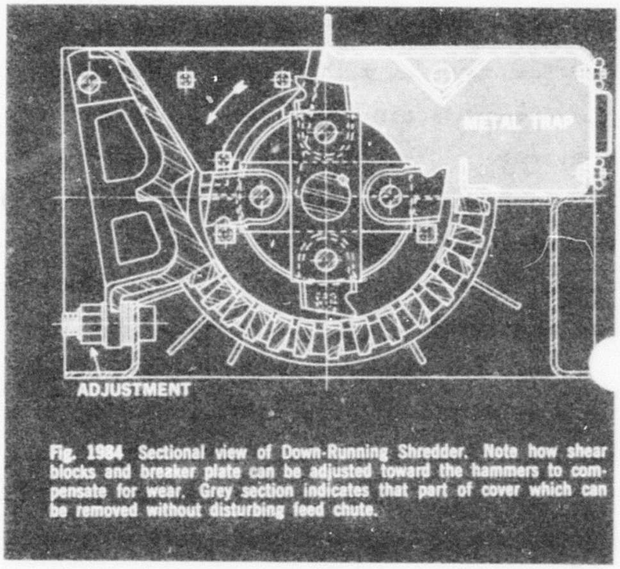


FIGURE J-12. SECTIONAL VIEW OF HAMMERMILL SHREDDER/GRINDER (2)

(1) Courtesy Jeffrey Manufacturing Co., Columbus, Ohio.
(2) Courtesy Williams Patent Crusher and Pulverizer Co., St. Louis, Missouri.

and bolts, or castings. Although equipment of this type is probably too large to be put on scene at a debris-recovery operation, virtually all categories of oil-soaked debris could be processed in these machines. The shredded debris could then be more easily incinerated, used for landfill, or perhaps even used for boiler fuel.

d. Transfer of Processed Oil/Debris

The preceding subsections described equipment which could be used to process debris or oil/debris mixtures by mulching, grinding, chipping, etc. The problem of transferring this processed oil/debris mixture to a temporary storage container remains. One promising kind of transfer device is the Moyno progressing cavity pump designed and manufactured by Robbins and Myers, Inc. of Springfield, Ohio. This type of pump consists of a long, cylindrical housing inside which is a flexible rubber, convoluted stator and a similarly shaped steel rotor. The rotor and stator are shaped so that as the rotor is driven, the cavities between rotor and stator progress along the length of the pump, thus causing the fluid in the pump to move down the length of the housing. The pumps are available in a number of sizes and styles to handle a wide range of liquid and liquid/solid-slurry pumping requirements. Some of these pumps are capable of pumping heavy crude oil mixed with 2-inch cubes or chips of wood.

Some centrifugal types of pumps such as the Gorman-Rupp solids-handling trash pumps manufactured by the Gorman-Rupp Company of Mansfield, Ohio, might also be suitable for transferring processed oil/debris slurries. These are available in a selection of sizes and, according to the manufacturer's claim, are capable of handling spherical solids up to 3 inches in diameter. Most other varieties of pumps (positive-displacement, piston, diaphragm, etc.) are less able to handle liquids with entrained solids of any appreciable size.

4. Solid-Waste-Disposal Equipment

a. Air Curtain Combustion Unit (ACCU)

The Camran Corporation of Seattle, Washington, has developed a portable device which picks up and burns stumps, logs, and brush without smoke. Shown in Figures J-13 and J-14, the ACCU consists of a hydraulic, grapple-equipped, articulated crane and a combustor unit mounted for easy transport on a road-going trailer. The large, open-topped combustor unit is fitted with forced-air ducting which provides draft for the fire and also effectively contains smoke and unconsumed small particles inside the unit with a curtain of air.

Although the unit does not meet the more stringent emission requirements of municipal incinerators, its manufacturer claims that it virtually eliminates visible emission(1). The unit has not been used to burn oil-soaked debris, but its makers feel that it would be able to burn virtually all categories of oil-soaked debris, even debris with significant (up to 60 percent) moisture content(2). A unit capable of handling 10 tons per hour has a top opening 20 by 12 feet, and larger units capable of burning 25 tons per hour can be furnished. The unit can be easily mounted on a barge and taken to the scene of oil/debris recovery.

The ACCU is a promising new development in the area of debris handling and could eliminate many of the debris storage, transfer, transport, and disposal problems which have been encountered in the past.

b. Trench Burners

The principle of controlled open burning is similar in concept to the ideas used in the Air Curtain Combustion Unit and is the basis for the line of Trench Burners marketed by Air Pollution Control Products, Inc. of Richmond, Virginia. The Trench Burner blower and special manifold supplies

(1) Sales literature from Camran Corporation, Seattle, Washington.

(2) Telephone conversation with John Miflin of Camran Corporation (January 2, 1974).

FIGURE J-13. CAMRAN AIR CURTAIN COMBUSTION UNIT(1)

(1) Courtesy Camran Corporation, Seattle, Washington

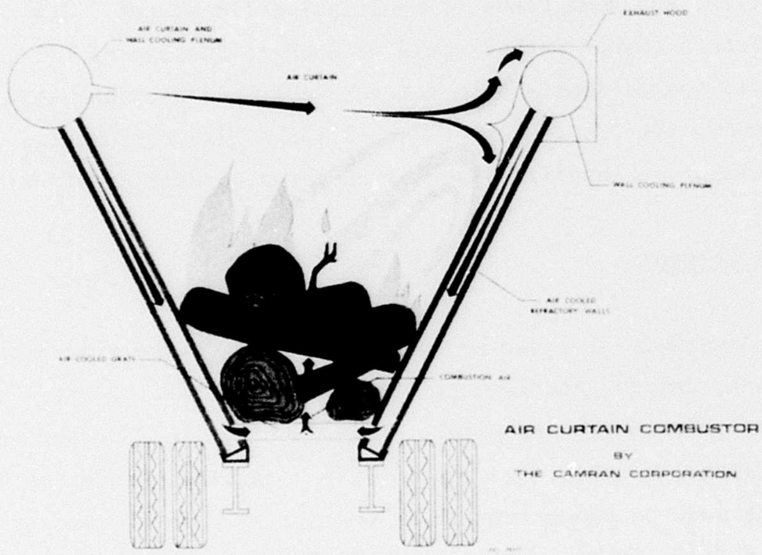


FIGURE J-14. PRINCIPLE OF OPERATION OF AIR CURTAIN COMBUSTION UNIT(1)

(1) Courtesy Camran Corporation, Seattle, Washington.

a curtain of forced air over a trench dug in the earth into which burnable debris is loaded as shown in the schematic in Figure J-15. The forced-air curtain supplies oxygen to the fire and keeps smoke and unconsumed particles from escaping to the atmosphere. Trench Burner units include a diesel-driven blower and 8-foot sections of manifold and can be supplied in various sizes for trenches up to 56 feet long. Trench Burners have been successfully used to dispose of logging wastes, debris from land clearance, demolition wastes, railroad ties, and some kinds of municipal solid wastes. Its makers feel that the Trench Burner method could be used to dispose of all categories of burnable oil-soaked debris with moisture contents as high as 50 percent[(1)]. Like the ACCU, the Trench Burner method looks like a promising alternative to open burning or landfill disposal of large quantities of oil-soaked debris.

c. Debris Screens

A variety of trash screens is used by sewage treatment plants to remove trash, debris, and garbage from sewage influent. These are generally very large, permanently installed, self-cleaning racks or screens set into sewage influent channels, and may include a garbage grinder or shredder. Some of the most common screen types consist of rows of equally spaced bars which can be set either vertically or inclined in the channel to trap debris. A series of rakes, with tines mounted on a moving chain or cable mechanism and spaced to protrude between the bars, lifts the trapped debris out of the water and dumps it into a collection bin or into a shredder. A rake-wiping mechanism is often employed to remove debris which does not fall off due to gravity. The entire raking mechanism, except for the protruding rake teeth, can be kept entirely downstream behind the bars to avoid jamming or mechanical damage, or it can be placed upstream. Typical spacing of bars in screens of this type is 4, 3, or 2 inches, although spacings of 1-1/2, 1, 3/4 inches or less can be furnished. Rake tines normally protrude 6 inches in front of the bars for trash-removal stations. Some bar screens are shown in Figures J-16, J-17, and J-18.

(1) Telephone conversation with William C. Taylor of Air Pollution Control Products, Inc. (January 2, 1974).

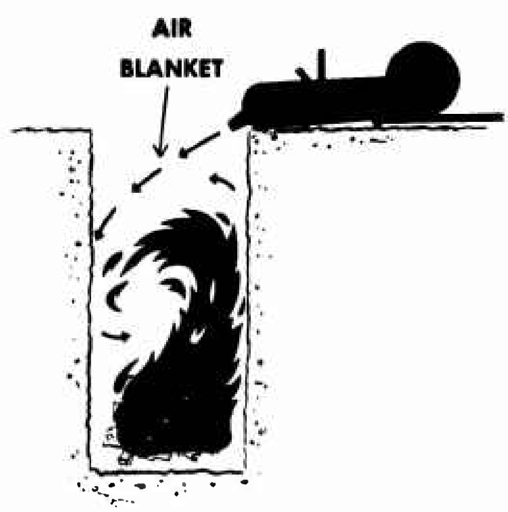


FIGURE J-15. PRINCIPLE OF OPERATION OF TRENCH BURNER (1)

(1) Courtesy Air Pollution Control Products, Richmond, Virginia.

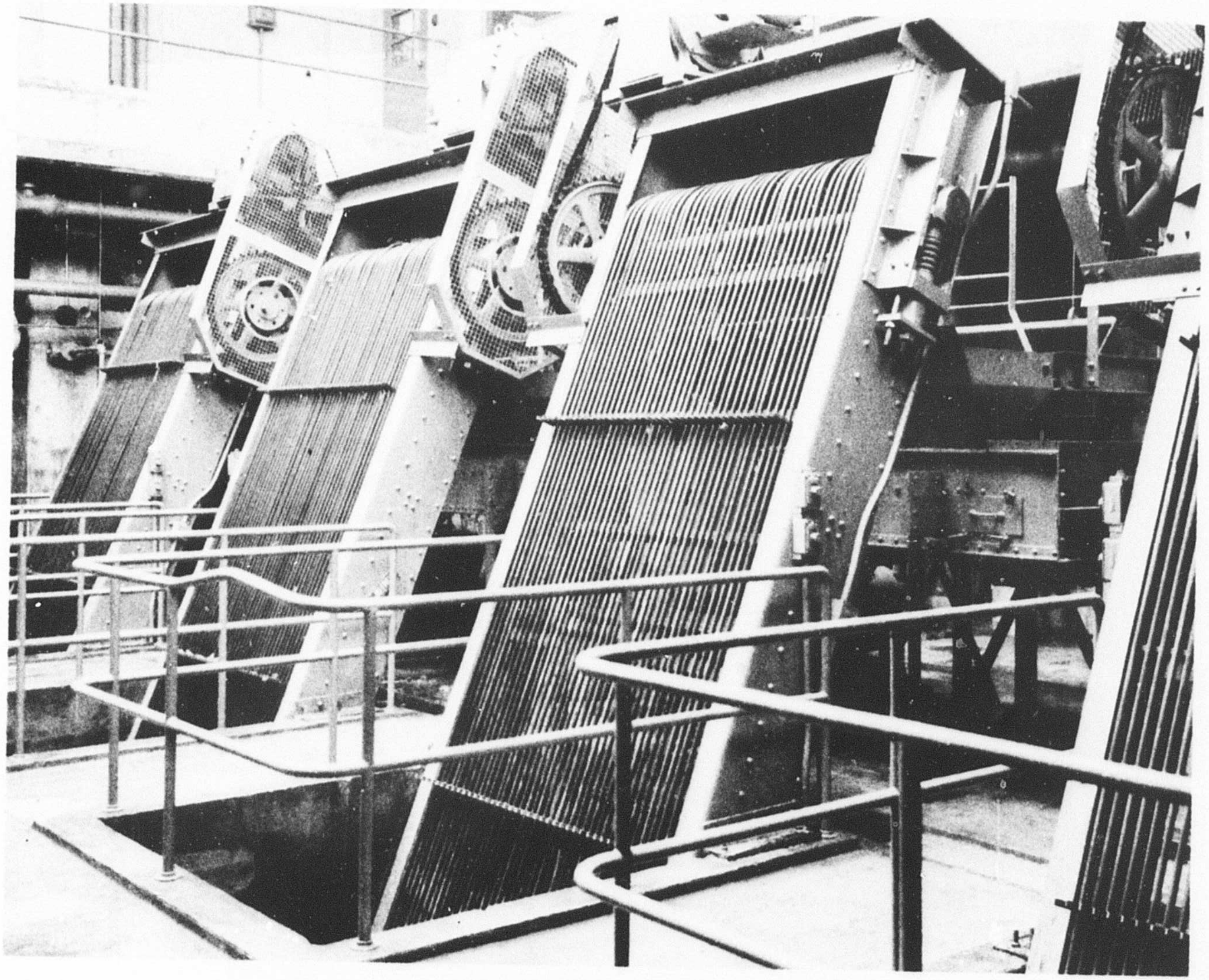


FIGURE J-16. TYPICAL BACK-CLEANED BAR RAKES[1]

(1) Courtesy Jeffrey Manufacturing Co., Columbus, Ohio.

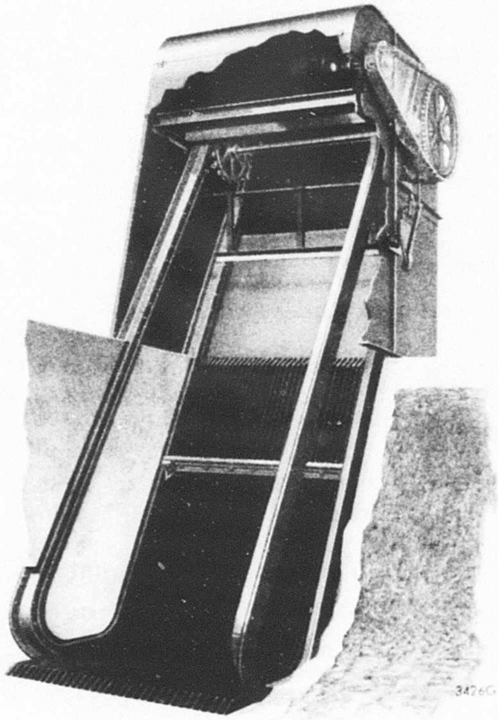


FIGURE J-17. FRONT-CLEANED BAR SCREEN (1)

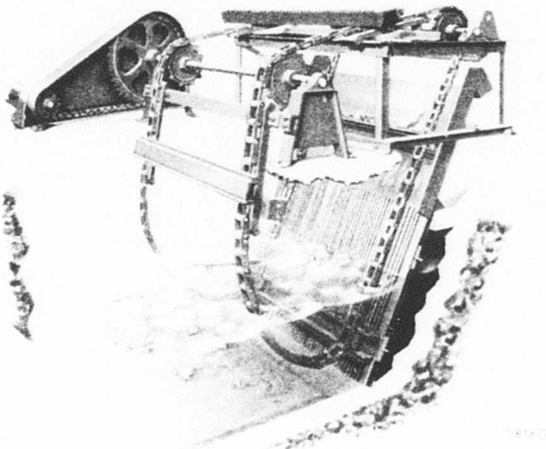


FIGURE J-18. CATENARY-TYPE FRONT-CLEANED BAR SCREEN (1)

(1) Courtesy Jeffrey Manufacturing Co., Columbus, Ohio.

Another variety of trash-removal screen is the travelling water screen used to filter water intake to power plants, refineries, pulp and paper mills, etc. As shown in Figures J-19 and J-20, this type consists of a continuous travelling screen set vertically into a channel and drawn by a chain or rollers. The screen mesh usually has a 3/8-inch grid opening, and trash-lifting lips or frames are placed on the screen about every 2 feet. The travelling screens can be operated continuously or intermittently depending on the quantity of debris encountered. The trash which clings to the trash screen is flushed off by high-pressure water jets inside the top housing. These screens are able to pick up most small categories of debris unless specially modified with wider lifting lips or inclined at an angle. Short-centered inclined screens with enormous carrying capacities have been furnished for bark removal in log flumes.

Although these travelling water screens and bar screens are very effective in recovering certain categories of debris, they are much better suited to permanent installation than they would be to handling wide varieties of debris from a mobile platform, as is required by most oil-spill cleanup operations.

d. Trash Racks

At power-plant water intakes, both thermal and hydroelectric, fixed bar racks are often placed in front of other debris screens to protect them from damage by large objects such as logs, tree limbs, oil cans, barrels, or bottles. Mechanized trash rakes, such as the one shown in Figure J-21, are often used to clear debris from these bar racks. In some applications the trash-rack mechanism is mounted on rails so it can move laterally and clean a series of side-by-side bar screens. This particular type is equipped with a patented rake design which allows the rake to ride over large items of debris as it is being lowered, and automatically positions itself for debris collection when it is raised. Trash rakes of this type will handle nearly all debris categories, except perhaps amorphous materials, up to medium sizes; but they are much better suited to permanent installation than they would be to mounting on a mobile platform such as a barge.

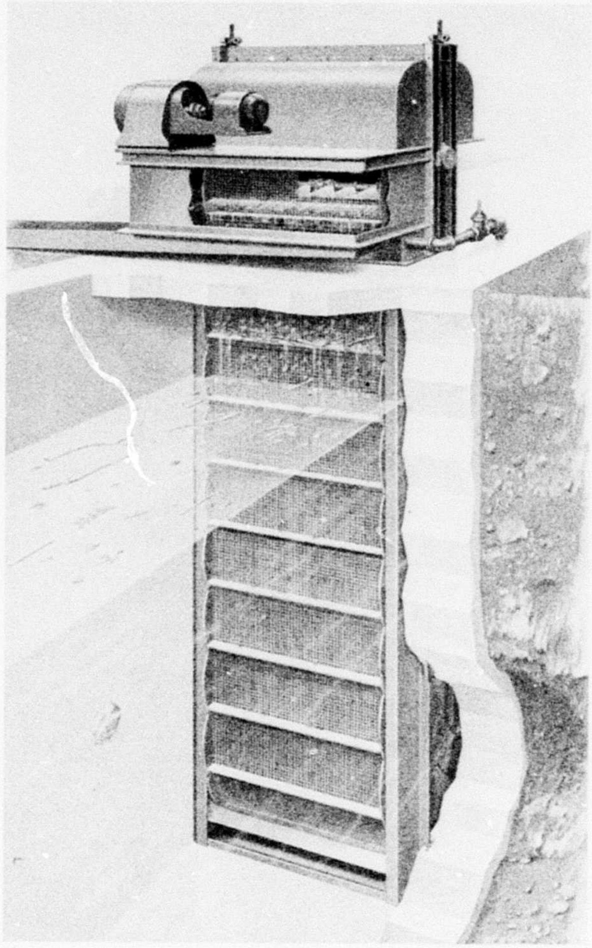


FIGURE J-19. CONTINUOUS TRAY-TYPE TRAVELLING WATER SCREEN (1)

(1) Courtesy Jeffrey Manufacturing Co., Columbus, Ohio

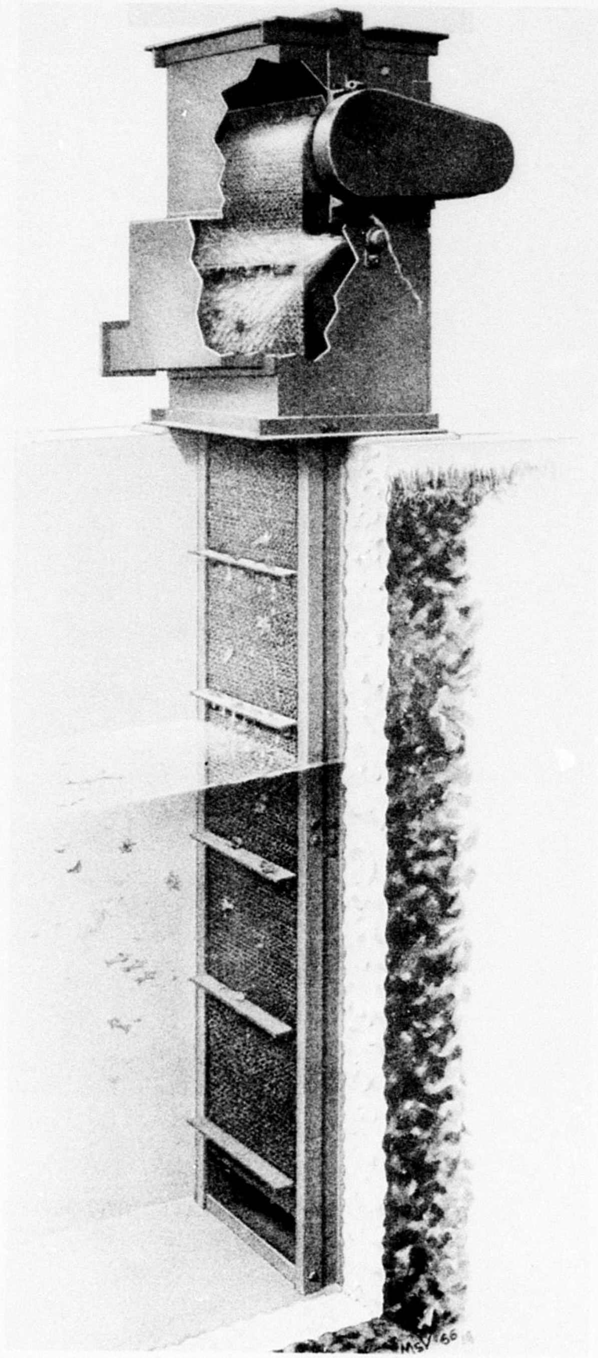


FIGURE J-20. CONTINUOUS BELT-TYPE TRAVELLING WATER SCREEN [1]

(1) Courtesy Jeffrey Manufacturing Co., Columbus, Ohio.

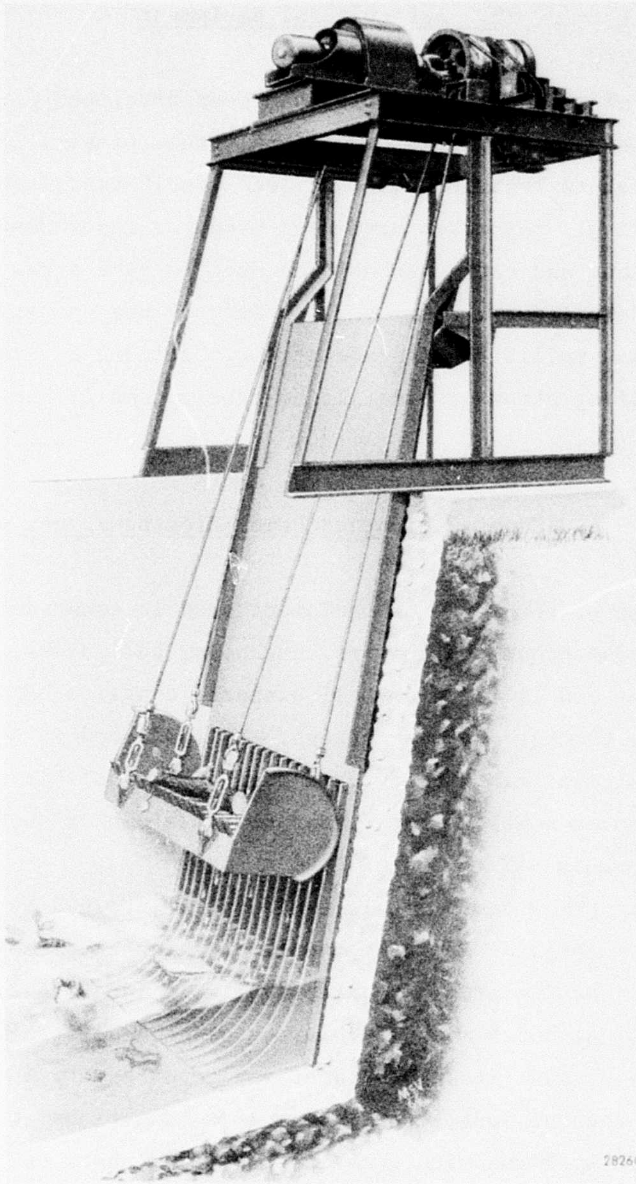


FIGURE J-21. JEFFREY-HUNT PATENTED TRASH RAKE [1]

(1) Courtesy Jeffrey Manufacturing Co., Columbus, Ohio.

5. Agricultural Equipment

Most of the equipment which has been developed for the farming industry such as combines, crop harvesters, fruit pickers, etc., is of such a specialized nature that it would not lend itself readily to the problem of debris handling. Hay rakes have been used for recovering oil-soaked straw from beaches and could probably be used to rake straw and other light categories of debris out of very shallow water. Hay and silage blowers have been used in past spills to dispense straw on slicks, but they are not suited for handling straw or other light debris once it has become wet or oil-soaked.

6. Construction and Demolition Equipment

A list of the kinds of equipment used in construction and demolition work includes front-end loaders, backhoes, bulldozers, graders, scrapers, hydraulic cranes and lifts, clamshell buckets, dragline buckets, earth-moving equipment, dump trucks, and many others. As indicated in Chapter III, nearly all of this equipment has already been used effectively in one past spill or another; and recommendations for the appropriate use of such equipment are included in Appendixes K through R.

Construction equipment is owned and maintained by private contractors and local, state, or Federal government agencies throughout the country; and much of this equipment can be made available for cleanup work in an oil-spill incident. Although much of this equipment is listed in local oil-spill contingency plans, additional equipment may be necessary in a major spill. The Associated General Contractors of America, a national organization of private contracting firms with local chapters and state offices throughout the country, has developed a program called Plan Bulldozer, which is designed to provide technical knowledge, personnel, and equipment, if requested, to Federal, state, county or city authorities in the event of a disaster or emergency situation such as a fire, flood, or earthquake. In some cases, Plan Bulldozer includes a listing of construction equipment which is owned by contractors in the AGC chapter's local area, whereas other chapters may

not maintain permanent lists of equipment because it changes hands frequently among member companies. In any case, the local AGC chapter can furnish valuable information concerning construction equipment, skilled operators, laborers, and supervisory personnel that might be available in the area. National headquarters for the AGC are in Washington, D. C., at the following address:

The Associated General Contractors of America
1957 E Street, N.W.
Washington, D. C. 20006
Telephone: (202) 393-2040

7. Dredging Equipment

Some of the equipment utilized in dredging operations has been investigated to determine its possible application in oil/debris cleanup. Although most of this kind of equipment, such as the cutting heads and associated rigging used to dig into the dredged channel bottom, is very highly specialized, the large, centrifugal pumps used to pump the dredge spoil would be capable of pumping huge quantities of oil/water/debris slurry. These pumps come in a variety of sizes and power ratings to suit specific dredging requirements. Some of the large pumps such as those used in the Ellicott Super Dragon Series 3000 dredges(1), are rated at 2,250 horsepower and discharge dredge spoil at rates of over 2,000 cubic yards per hour through pipes up to 24 inches I.D. Large solid items such as rocks, metal cans, and pieces of lumber, will pass right through a pump of this size. The pumps are equipped with special high-chrome-carbide-steel-alloy parts to resist abrasion. Although these pumps could conceivably be used to advantage in very large spills, their application to most spills would be limited.

8. Fishing-Industry Equipment

Like other industries, the fishing industry uses many types of specially designed equipment which would not be suitable as is for debris

(1) Descriptive literature, Ellicott Machine Corporation, 1600 Bush Street, Baltimore, Maryland 21230.

handling, but some of the design concepts developed for this industry could be modified for effective debris-handling functions.

a. Trawler Nets

As mentioned in an earlier section of this report (Chapter III, D), the use of gill nets towed behind fishing vessels to corral floating oil slicks and debris on the open ocean has been discussed but not reported as having been used in actual practice. As indicated in Chapter II, debris in the open ocean is generally not nearly as serious a problem as it is in protected waters, but the oil-soaked debris which is encountered in the open ocean can be recovered more easily if it is first contained and concentrated by some kind of barrier. A suitably modified fishing net towed in a catenary between two fishing boats could be used for this purpose. Many nets are rigged to be towed entirely beneath the water surface, but floats can be rigged to keep one edge of the net above the surface to collect debris. Most seine-type or trawler-type nets are strong enough to contain all categories of debris up to medium-sized pieces. Fishing nets could not be used in protected water which is shallow, restricted, or subject to very swift currents; but they could be used in wide expanses of most navigable harbors such as San Francisco Bay, Chesapeake Bay, Delaware Bay, etc. Further investigation into the feasibility of using fishing nets for debris containment or diversion is recommended.

b. Travelling Fish Screens

For many years biologists and engineers have tried to develop ways of protecting juvenile salmon, shad, and striped bass from being killed in rivers that have hazardous hydroelectric and thermal power-plant cooling-water intakes, and irrigation projects. The reference[1] describes travelling

(1) Bates, D. W., and J. G. Vandewalker, "Preliminary Design of Traveling Screens to Collect Juvenile Fish", United States Fish and Wildlife Service, Special Scientific Report, Fisheries No. 608, Washington, D.C. (July 1970).

fish screens which were developed by the Bureau of Commercial Fisheries to divert these young fish to bypass channels which carried them safely downstream of the hazard.

As shown in Figure J-22, the screen consists basically of a wire-mesh conveyor set on edge and placed diagonally in the stream across the path of the fish. The screen was driven so that the upstream side moved in the same direction as the downstream flow. The screens have proven very effective in safeguarding fish, but they have also been susceptible to damage from heavy debris.

The reference below(1) describes the design of a travelling debris screen which was developed by the National Marine Fisheries Service specifically to protect travelling-fish-screen installations. As shown in Figures J-23 through J-27, the debris screen is of the same basic design as the fish screen--a conveyor belt placed on edge in a diagonal line (20-degree angle to direction of stream) across the debris path. Debris which impinges the screen is diverted easily into a quiet pond for removal by conveyor, trash rake, crane, etc. The screen was constructed of heavy torpedo netting and suspended from a cable-supported steel frame.

The debris screen was effective in directing branches and logs up to a weight of 1,362 kilograms (approximately 3,000 pounds), and branches which became enmeshed in the screen freed themselves at the downstream end of the screen. Long streamers of moss floating downstream in the fall had to be picked by hand from the screen.

The screen would be effective in diverting nearly all medium and large categories of debris except perhaps filamentous pieces and amorphous materials. Although this particular design would seem to lend itself more readily to permanent installations, the application of the moving-debris-screen principle could be applied to mobile debris-containment or diversion equipment. Portable travelling debris screens could be deployed across swift-running rivers or streams, harbor entrances, boat slips, marinas, etc. Further research into the application of travelling debris screens to debris-handling problems is recommended.

---

(1) Bates, D. W., E. V. Murphey, and M. G. Beam, "Traveling Screen for Removal of Debris From Rivers", NOAA Technical Report NMFS SSRF-645, Seattle, Washington (October 1971).

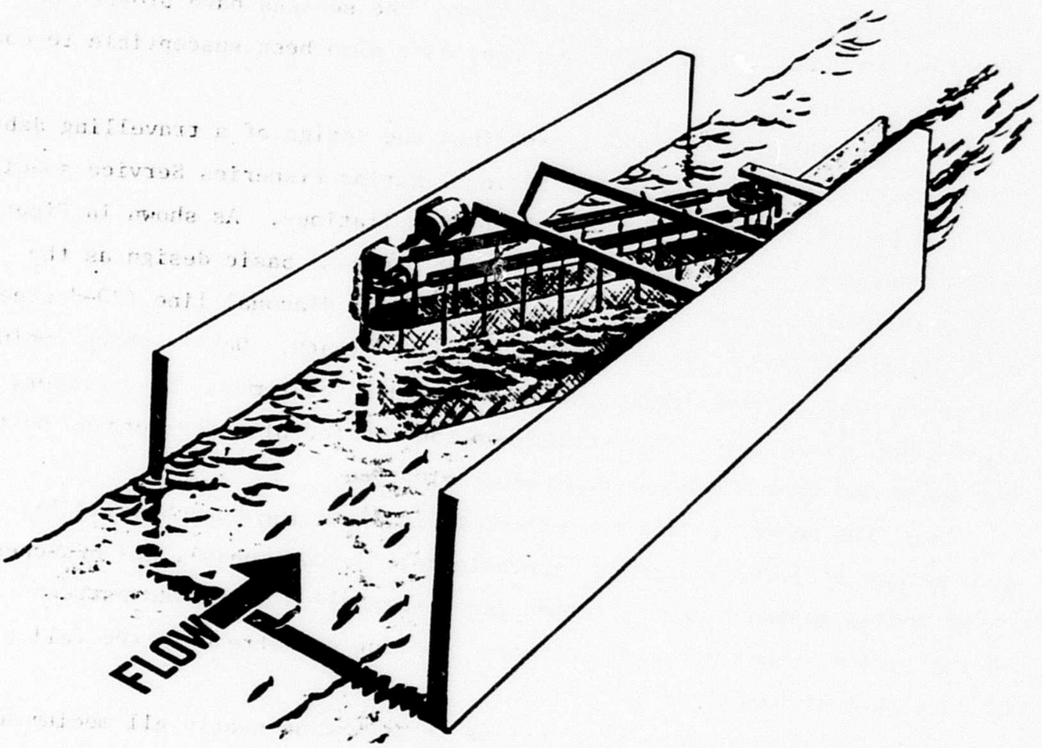


FIGURE J-22. TRAVELLING FISH SCREEN(1)

(1) Bates and Vandewalker, op cit, p. 2.

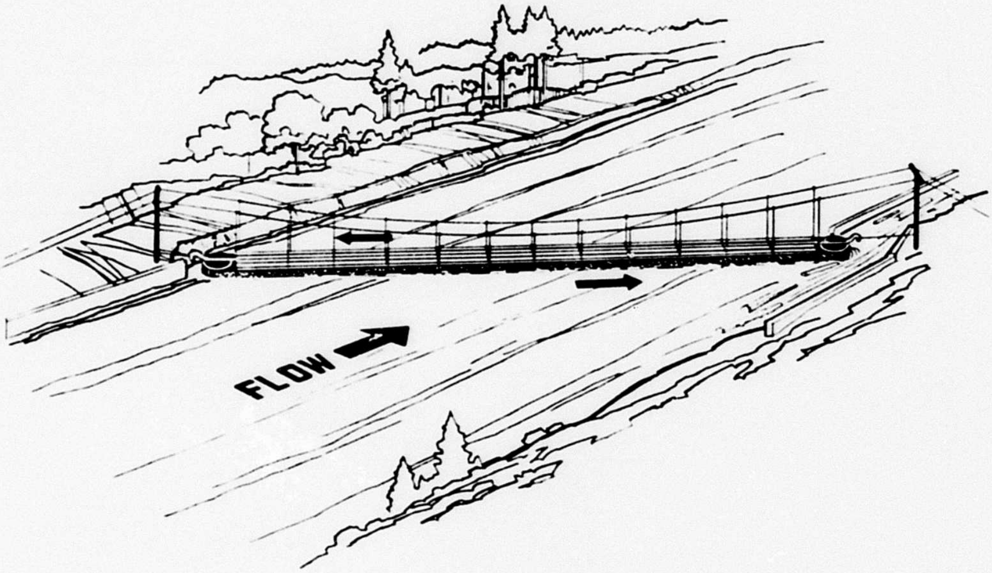


FIGURE 4-23. THE TRAVELLING DEBRIS SCREEN AND SUPPORTING STRUCTURE[1]

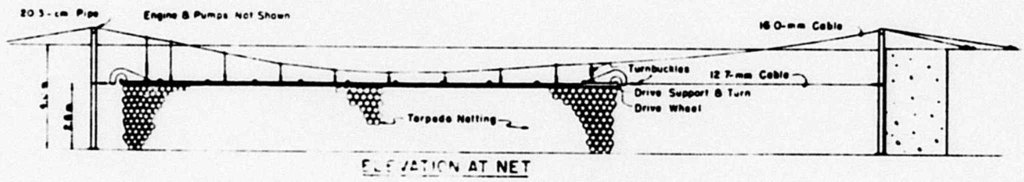


FIGURE 4-24. ELEVATION VIEW OF TRAVELLING DEBRIS SCREEN[1]

(1) Bates, Murphey, and Beam, op cit, p. 2.

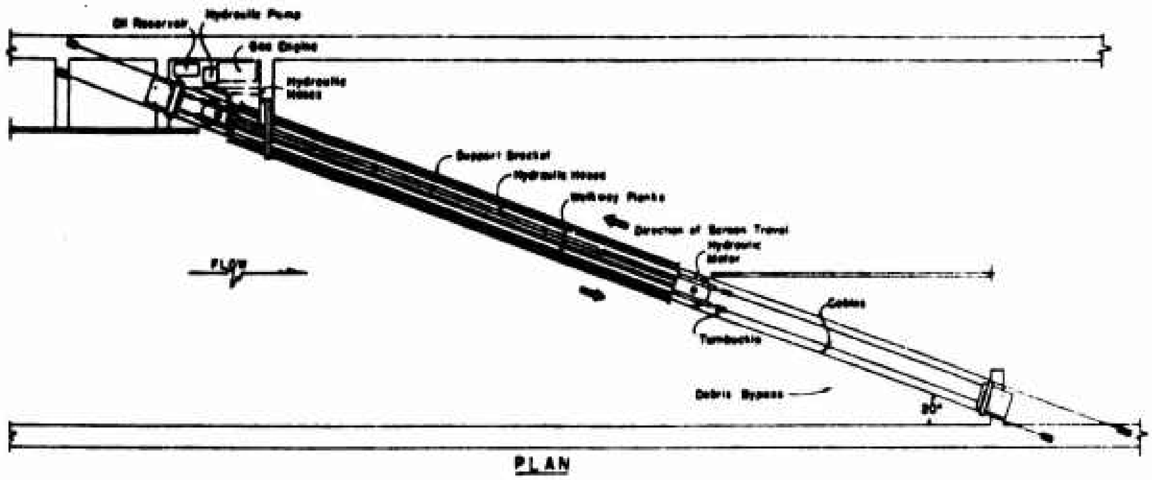


FIGURE J-25. PLAN VIEW OF THE TRAVELLING DEBRIS SCREEN(1)

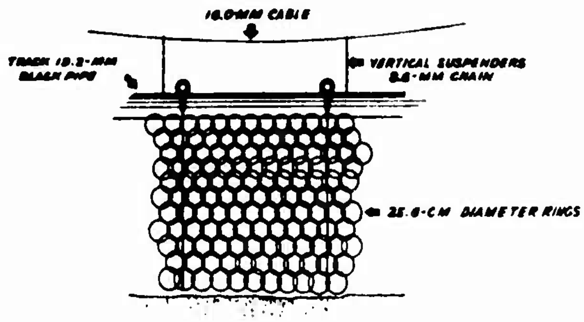


FIGURE J-26. ELEVATION VIEW OF A SECTION OF THE TRAVELLING DEBRIS SCREEN(1)

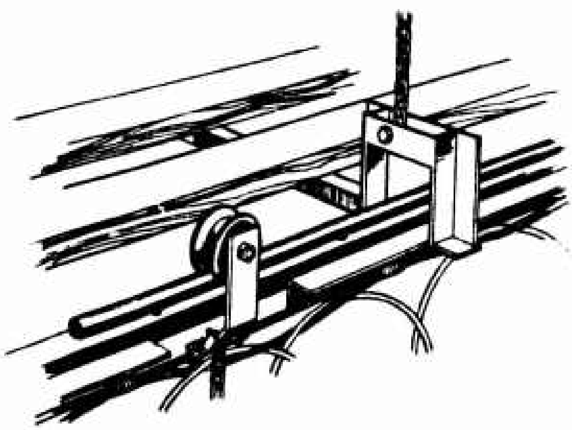


FIGURE J-27. VIEW OF TRACK AND CARRIAGE SYSTEM OF TRAVELLING DEBRIS SCREEN(2)

(1) Bates and Vandewalker, op cit, p. 4.

(2) Bates and Vandewalker, op cit, p. 3

APPENDIX K

EVALUATION OF DEBRIS CONTAINMENT/DIVERSION METHODS

This appendix contains an evaluation of methods that have been used in past spills for containing or diverting debris.

The notation in the body of each table consists of O's, X's, and XX's, some of which are underlined. The significance of each symbol is as follows:

> An "O" means that, for a given function (table heading) and situation (table subheading), the particular technique or type of equipment (column heading) is considered unacceptable, and is not recommended for coping with that particular debris category (line heading). Thus, for example, commercially available oil barriers are not recommended for containment/diversion of large general wood items in protected water where the current is less than 1/2 knot.
>
> A single "X" means that, for a given function and situation, the particular technique or type of equipment is acceptable but not highly recommended for coping with that particular debris category. For example, log booms are acceptable for containment/diversion of medium-sized general wood items in protected water where the current is less than 1/2 knot.
>
> "XX" signifies that the particular technique or type of equipment is preferred and highly recommended. Thus, utilization of natural debris-collecting areas is a highly recommended technique for containment/diversion of all debris categories in protected water with current less than 1/2 knot.
>
> Items which are underlined are those which were observed or reported as having been used in previous oil spills for that particular combination of function, situation, and debris category. Absence of an underline means that no information was found regarding application in past spills for the particular function, situation, and debris category. Underlined items, therefore, define examples of the state of the art in debris handling.

Some column headings are marked with an asterisk (*), and none of the items in these columns are underlined. These columns represent techniques or types of equipment which are available or in use in other industries, but which the information available indicates have never been applied to the problem of debris handling in an oil spill. It is significant that some of the items in these columns are recommended more highly than other items which actually have been used.

TABLE K.

SITUATION I: Protected water; current less than 1/2 knot; containment recommended.	Commercially available oil boom	Some ruggedly constructed oil booms	Log booms	Fixed wire-mesh or chain-link type fences	Wire-mesh or chain-link type floating booms	High-pressure water hoses	Propeller wash from small boats
DEBRIS CATEGORY:							
I. General Wood Items							
A. Small	X	XX	X	X	X	X	X
B. Medium	0	X	X	X	X	X	X
C. Large	0	X	XX	X	X	0	0
II. Non-Rigid Shapes							
A. Small	X	XX	X	X	X	X	X
B. Large	X	X	XX	X	X	0	0
III. Rigid Shapes							
A. Small	X	XX	X	X	X	X	X
B. Medium	0	X	X	X	X	X	X
C. Large	0	X	XX	X	X	0	0
IV. Flexible Sheets							
A. Small	X	XX	X	X	X	X	X
B. Large	X	XX	XX	X	X	0	X
V. Rigid Sheets							
A. Small	X	XX	X	X	X	X	X
B. Medium	0	X	X	X	X	X	X
C. Large	0	X	XX	X	X	0	0
VI. Amorphous Materials	X	XX	X	X	X	X	X
VII. Filamentous Pieces							
A. Individual Pieces	X	XX	X	X	X	0	X
B. Groups of Pieces	X	XX	X	X	X	0	X
VIII. Special Cases	0	X	X	X	X	X	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

Debris Category	Propeller wash from powerful boats	Fixed cable-reinforced* wire-mesh or chain-link fences	Cable-reinforced wire-mesh or chain-link fence-type booms	Manual diversion with boat hooks, pike poles, gaffs, rakes, etc.	Air-bubble barriers	Air jets	Utilization of natural debris-collecting areas	Towing of individual items by boat
I.								
A.	X	X	X	X	X	X	XX	0
B.	X	X	X	X	X	0	XX	0
C.	X	X	X	X	0	0	XX	X
II.								
A.	X	X	X	X	X	X	XX	0
B.	X	X	X	X	0	0	XX	X
III.								
A.	X	X	X	X	X	X	XX	0
B.	X	X	X	X	X	0	XX	0
C.	X	X	X	X	0	0	XX	0
IV.								
A.	X	X	X	X	X	0	XX	X
B.	X	X	X	X	X	0	XX	0
V.								
A.	X	X	X	X	X	X	XX	0
B.	X	X	X	X	X	0	XX	0
C.	X	X	X	X	0	0	XX	X
VI.	X	X	X	X	X	X	XX	0
VII.								
A.	X	X	X	X	X	X	XX	0
B.	X	X	X	X	X	X	XX	0
VIII.	X	X	X	X	0	0	XX	X

* – Recommended alternative to current practice, not reported previously used.

TABLE K.

SITUATION II: Protected water; currents up to about 2 knots; containment difficult; diversion to natural collecting areas recommended.	Commercially available oil boom	Some ruggedly constructed oil booms	Log booms	Fixed wire-mesh or chain-link type fences	Wire-mesh or chain-link type floating booms	High-pressure water hoses	Propeller wash from small boats
DEBRIS CATEGORY:							
I. General Wood Items							
A. Small	0	X	X	X	X	0	X
B. Medium	0	X	X	X	X	0	0
C. Large	0	0	X	0	0	0	0
II. Non-Rigid Shapes							
A. Small	0	X	X	X	X	0	X
B. Large	0	0	X	0	0	0	0
III. Rigid Shapes							
A. Small	0	X	X	X	X	0	X
B. Medium	0	X	X	X	X	0	0
C. Large	0	0	X	0	0	0	0
IV. Flexible Sheets							
A. Small	0	X	X	X	X	0	X
B. Large	0	0	X	0	0	0	0
V. Rigid Sheets							
A. Small	0	X	X	X	X	0	X
B. Medium	0	X	X	X	X	0	0
C. Large	0	0	X	0	0	0	0
VI. Amorphous Materials	0	X	X	X	X	0	0
VII. Filamentous Pieces							
A. Individual Pieces	0	X	X	X	X	0	X
B. Groups of Pieces	0	X	X	X	X	0	X
VIII. Special Cases	0	0	X	X	X	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Debris Category	Propeller wash from powerful boats	Fixed cable-reinforced* wire-mesh or chain-link fences	Cable-reinforced wire-mesh or chain-link fence-type booms	Manual diversion with boat hooks, pike poles, gaffs, rakes, etc.	Air-bubble barriers	Air jets	Utilization of natural debris-collecting areas	Towing of individual items by boat
I.								
A.	X	X	X	X	0	0	XX	0
B.	X	X	X	X	0	0	XX	0
C.	X	X	X	0	0	0	XX	X
II.								
A.	X	X	X	X	0	0	XX	0
B.	X	X	X	0	0	0	XX	X
III.								
A.	X	X	X	X	0	0	XX	0
B.	X	X	X	X	0	0	XX	0
C.	X	X	X	0	0	0	XX	X
IV.								
A.	X	X	X	X	0	0	XX	0
B.	X	X	X	0	0	0	XX	X
V.								
A.	X	X	X	X	0	0	XX	0
B.	X	X	X	X	0	0	XX	0
C.	X	X	X	0	0	0	XX	X
VI.	X	X	X	X	0	0	XX	0
VII.								
A.	X	X	X	X	0	0	XX	0
B.	X	X	X	X	0	0	XX	0
VIII.	X	X	X	0	0	0	XX	X

* - Recommended alternative to current practice, not reported previously used.

TABLE K.

SITUATION III: Protected waters; up to 6-knot currents; containment extremely difficult; diversion to natural collecting areas recommended. DEBRIS CATEGORY:	Commercially available oil boom	Some ruggedly constructed oil booms	Log booms	Fixed wire-mesh or chain-link type fences	Wire-mesh or chain-link type floating booms	High-pressure water hoses	Propeller wash from small boats
I. General Wood Items							
A. Small	0	0	X	0	0	0	0
B. Medium	0	0	X	0	0	0	0
C. Large	0	0	X	0	0	0	0
II. Non-Rigid Shapes							
A. Small	0	0	X	0	0	0	0
B. Large	0	0	X	0	0	0	0
III. Rigid Shapes							
A. Small	0	0	X	0	0	0	0
B. Medium	0	0	X	0	0	0	0
C. Large	0	0	X	0	0	0	0
IV. Flexible Sheets							
A. Small	0	0	X	0	0	0	0
B. Large	0	0	X	0	0	0	0
V. Rigid Sheets							
A. Small	0	0	X	0	0	0	0
B. Medium	0	0	X	0	0	0	0
C. Large	0	0	X	0	0	0	0
VI. Amorphous Materials	0	0	X	0	0	0	0
VII. Filamentous Pieces							
A. Individual Pieces	0	0	X	0	0	0	0
B. Groups of Pieces	0	0	X	0	0	0	0
VIII. Special Cases	0	0	X	0	0	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Debris Category	Propeller wash from powerful boats	Fixed cable-reinforced* wire-mesh or chain-link fences	Cable-reinforced wire-mesh or chain-link fence-type booms	Manual diversion with boat hooks, pike poles, gaffs, rakes, etc.	Air-bubble barriers	Air jets	Utilization of natural debris-collecting areas	Towing of individual items by boat
I.								
A.	0	X	X	0	0	0	XX	0
B.	0	X	X	0	0	0	XX	0
C.	0	X	X	0	0	0	XX	0
II.								
A.	0	X	X	0	0	0	XX	0
B.	0	X	X	0	0	0	XX	0
III.								
A.	0	X	X	0	0	0	XX	0
B.	0	X	X	0	0	0	XX	0
C.	0	X	X	0	0	0	XX	0
IV.								
A.	0	X	X	0	0	0	XX	0
B.	0	X	X	0	0	0	XX	0
V.								
A.	0	X	X	0	0	0	XX	0
B.	0	X	X	0	0	0	XX	0
C.	0	X	X	0	0	0	XX	0
VI.	0	X	X	0	0	0	XX	0
VII.								
A.	0	X	X	0	0	0	XX	0
B.	0	X	X	0	0	0	XX	0
VIII.	0	X	X	0	0	0	XX	0

* - Recommended alternative to current practice, not reported previously used.

SITUATION IV: Open ocean; containment barriers not recommended except under very calm conditions.	Commercially available oil boom	Some ruggedly constructed oil booms	Log booms	Fixed wire-mesh or chain-link type fences	Wire-mesh or chain-link type floating booms	High-pressure water hoses	Propeller wash from small boats
DEBRIS CATEGORY:							
I. General Wood Items							
A. Small	<u>X</u>	<u>X</u>	0	0	X	0	0
B. Medium	<u>0</u>	<u>X</u>	0	0	X	0	0
C. Large	<u>0</u>	<u>0</u>	0	0	0	0	0
II. Non-Rigid Shapes							
A. Small	<u>X</u>	<u>X</u>	0	0	X	0	0
B. Large	<u>0</u>	<u>0</u>	0	0	0	0	0
III. Rigid Shapes							
A. Small	<u>X</u>	<u>X</u>	0	0	X	0	0
B. Medium	<u>0</u>	<u>X</u>	0	0	X	0	0
C. Large	<u>0</u>	<u>0</u>	0	0	0	0	0
IV. Flexible Sheets							
A. Small	<u>X</u>	<u>X</u>	0	0	X	0	0
B. Large	<u>0</u>	<u>X</u>	0	0	X	0	0
V. Rigid Sheets							
A. Small	<u>X</u>	<u>X</u>	0	0	X	0	0
B. Medium	<u>0</u>	<u>X</u>	0	0	X	0	0
C. Large	<u>0</u>	<u>0</u>	0	0	0	0	0
VI. Amorphous Materials	<u>X</u>	<u>X</u>	0	0	X	0	0
VII. Filamentous Pieces							
A. Individual Pieces	<u>X</u>	<u>X</u>	0	0	X	0	0
B. Groups of Pieces	<u>X</u>	<u>X</u>	0	0	X	0	0
VIII. Special Cases	<u>0</u>	<u>X</u>	0	0	0	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Debris Category	Propeller wash from powerful boats	Fixed cable-reinforced wire-mesh or chain-link fences	Cable-reinforced wire-mesh or chain-link fence-type booms	Manual diversion with boat hooks, pike poles, gaffs, rakes, etc.	Air-bubble barriers	Air jets	Utilization of natural debris-collecting areas	Towing of individual items by boat
I.								
A.	0	0	X	X	0	0	0	0
B.	0	0	X	X	0	0	0	0
C.	0	0	X	X	0	0	0	X
II.								
A.	0	0	X	X	0	0	0	0
B.	0	0	X	X	0	0	0	X
III.								
A.	0	0	X	X	0	0	0	0
B.	0	0	X	X	0	0	0	0
C.	0	0	X	X	0	0	0	X
IV.								
A.	0	0	X	X	0	0	0	0
B.	0	0	X	X	0	0	0	0
V.								
A.	0	0	X	X	0	0	0	0
B.	0	0	X	X	0	0	0	0
C.	0	0	X		0	0	0	0
VI.	0	0	X	X	0	0	0	0
VII.								
A.	0	0	X	X	0	0	0	0
B.	0	0	X	X	0	0	0	0
VIII.	0	0	X	X	0	0	0	X

APPENDIX L

EVALUATION OF METHODS OF RECOVERING FLOATING DEBRIS

Appendix L contains evaluations of methods of recovering debris that is floating on the water.

For the key to symbols, refer to page 389.

Preceding page blank

TABLE L. RECOVERY

SITUATION I: Protected navigable waters; debris contained and/or concentrated by natural or artificial barrier; may be near shore; little or no current; equipment can be barge- or boat-mounted or operated from shore.	Wire-mesh basket on articulated hydraulic crane or backhoe	Crane-mounted wire-mesh dragline-type basket	Front-end loading wire-mesh basket or rake	Clamshell-bucket-equipped crane	Debris conveyors	Oleophilic belt-type skimmers	Rakes, shovels, pitchforks, dip nets, etc.	Chain-link or wire-mesh nets between catamaran hulls
DEBRIS CATEGORY:								
I. General Wood Items								
A. Small	X̲X̲	X̲X̲	X̲	X̲	X̲X̲	X̲	X̲	X̲
B. Medium	X̲X̲	X̲X̲	X̲	X̲	X	0	0̲	X̲
C. Large	X̲	X̲	X	X̲	0	0	0	X̲
II. Non-Rigid Shapes								
A. Small	XX	X̲X̲	X̲	X̲	X	X	X̲	X̲
B. Large	XX	X̲X̲	X̲	X̲	X	0	0	X̲
III. Rigid Shapes								
A. Small	XX	X̲X̲	X̲	X̲	XX	X	X̲	0̲
B. Medium	XX	X̲X̲	X̲	X̲	X	0	0	X̲
C. Large	X	X̲	X	X̲	0	0	0	X̲
IV. Flexible Sheets								
A. Small	XX	X̲X̲	X̲	X̲X̲	X	X	X̲	X̲
B. Large	X	X̲	X̲	X̲X̲	0	0	0	X̲
V. Rigid Sheets								
A. Small	XX	X̲X̲	X̲	X̲	X̲X̲	X̲	X̲	0̲
B. Medium	XX	X̲X̲	X̲	X̲	X	0	0	X̲
C. Large	X	X̲	X	X̲	0	0	0	X̲
VI. Amorphous Materials	X̲	X̲	X	X̲	XX	X̲X̲	X̲	0̲
VII. Filamentous Pieces								
A. Individual Pieces	X̲	X̲	X̲	X̲	0	0̲	X̲	X̲
B. Groups of Pieces	X̲	X̲	X̲	X̲	0	0̲	X̲	X̲
VIII. Special Cases	X̲	X̲	X̲	X̲X̲	0	0	0	X̲

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

Crane-mounted wire-mesh basket hung over side or bow of vessel	Trash or debris rakes mounted on hydraulic boom*	Pulpwood or scrap grapple*	Log grapple*	Chain-drag log conveyor*	Hand or power winch	Ice tongs, pike poles, spikes, etc.	Crane-mounted rope, fabric, or wire sling *	Vacuum hoses	Special pumps	Kelp harvesters*
X	X	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	X	0	0	0
0	0	X	XX	X	X	0	X	0	0	0
X	X	0	0	0	0	X	0	0	0	0
X	X	X	X	0	X	0	X	0	0	0
X	0	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	X	0	0	0
0	0	X	XX	X	X	0	X	0	0	0
X	X	X	X	0	0	X	0	0	0	0
X	X	XX	X	0	X	X	0	0	0	0
X	0	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	X	0	0	0
0	0	X	XX	X	X	0	X	0	0	0
X	X	0	0	0	0	0	0	X	X	0
X	X	X	X	0	0	X	0	0	0	X
X	X	X	X	0	0	X	0	0	0	X
X	X	XX	X	0	X	X	X	0	0	0

* - Recommended alternative to current practice, not reported previously used.

TABLE L.

SITUATION II: Protected navigable waters; debris uncontained by barriers; currents, winds, wave heights variable; equipment can be permanently mounted on suitable vessel, or temporarily mounted on vessel of opportunity (e.g. LCM, LCU, barge, etc.).	Wire-mesh basket on articulated hydraulic crane or backhoe	Crane-mounted wire-mesh dragline-type basket	Front-end loading wire-mesh basket on rake	Clamshell-bucket-equipped crane	Debris conveyors	Oleophilic belt-type skimmers	Rakes, shovels, pitch-forks, dip nets, etc.	Chain-link or wire-mesh nets between catamaran hulls
DEBRIS CATEGORY:								
I. General Wood Items								
A. Small	XX	X	XX	0	X	X	0	XX
B. Medium	XX	X	XX	0	X	0	0	XX
C. Large	X	X	X	0	0	0	0	XX
II. Non-Rigid Shapes								
A. Small	XX	X	XX	0	X	X	0	XX
B. Large	XX	X	XX	0	X	0	0	XX
III. Rigid Shapes								
A. Small	XX	X	XX	0	X	X	0	0
B. Medium	XX	X	XX	0	X	0	0	XX
C. Large	X	X	X	0	0	0	0	XX
IV. Flexible Sheets								
A. Small	XX	X	XX	0	X	X	0	XX
B. Large	X	X	XX	0	0	0	0	XX
V. Rigid Sheets								
A. Small	XX	X	XX	0	X	X	0	0
B. Medium	XX	X	XX	0	X	0	0	XX
C. Large	X	X	X	0	0	0	0	XX
VI. Amorphous Materials	X	X	XX	0	X	XX	0	0
VII. Filamentous Pieces								
A. Individual Pieces	X	X	X	0	0	0	0	XX
B. Groups of Pieces	X	X	X	0	0	0	0	XX
VIII. Special Cases	X	X	XX	0	0	0	0	XX

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Crane-mounted wire-mesh basket hung over side or bow of vessel	Trash or debris rakes mounted on hydraulic boom*	Pulpwood or scrap grapple*	Log grapple*	Chain-drag log conveyor*	Hand or power winch	Ice tongs, pike poles, spikes, etc.	Crane-mounted rope, fabric, or wire sling*	Vacuum hoses	Special pumps	Kelp harvesters*
XX	X	0	0	0	0	0	0	0	0	0
XX	X	X	X	0	0	0	X	0	0	0
0	0	X	XX	0	X	0	X	0	0	0
XX	X	0	0	0	0	0	0	0	0	0
X	X	X	X	0	X	0	X	0	0	0
XX	0	0	0	0	0	0	0	0	0	0
XX	X	X	X	0	0	0	X	0	0	0
0	0	X	X	0	X	0	X	0	0	0
XX	X	X	X	0	0	0	0	0	0	0
X	X	X	X	0	X	0	0	0	0	0
XX	0	0	0	0	0	0	0	0	0	0
XX	X	X	X	0	0	0	X	0	0	0
0	0	X	X	0	X	0	X	0	0	0
XX	X	0	0	0	0	0	0	0	0	0
X	X	X	X	0	0	0	0	0	0	X
X	X	X	X	0	0	0	0	0	0	X
X	X	X	X	0	X	0	X	0	0	0

* - Recommended alternative to current practice, not reported previously used.

SITUATION III: Open ocean; debris contained and/or concentrated by artificial barrier; equipment can be permanently mounted on suitable vessel or temporarily mounted on vessel of opportunity (e.g. LCM, LCU, barge, etc.).	Wire-mesh basket on articulated hydraulic crane or backhoe	Crane-mounted wire-mesh dragline-type basket	Front-end loading wire-mesh basket or rake	Clamshell-bucket-equipped crane	Debris conveyors	Oleophilic belt-type skimmers	Rakes, shovels, pitch-forks, dip nets, etc.	Chain-link or wire-mesh nets between catamaran hulls
DEBRIS CATEGORY:								
I. General Wood Items								
A. Small	XX	XX	X	X	XX	X	X	0
B. Medium	XX	XX	X	X	X	0	0	0
C. Large	X	X	X	X	0	0	0	0
II. Non-Rigid Shapes								
A. Small	XX	XX	X	X	X	X	X	0
B. Large	XX	XX	X	X	X	0	0	0
III. Rigid Shapes								
A. Small	XX	XX	X	X	XX	X	X	0
B. Medium	XX	XX	X	X	X	0	0	0
C. Large	X	X	X	X	0	0	0	0
IV. Flexible Sheets								
A. Small	XX	XX	X	XX	X	X	X	0
B. Large	X	X	X	XX	0	0	0	0
V. Rigid Sheets								
A. Small	XX	XX	X	X	XX	X	X	0
B. Medium	XX	XX	X	X	X	0	0	0
C. Large	X	X	X	X	0	0	0	0
VI. Amorphous Materials	X	X		X	XX	XX	X	0
VII. Filamentous Pieces								
A. Individual Pieces	X	X	X	X	0	0	X	0
B. Groups of Pieces	X	X	X	X	0	0	X	0
VIII. Special Cases	X	X	X	XX	0	0	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Crane-mounted wire-mesh basket hung over side or bow of vessel	Trash or debris rakes mounted on hydraulic boom*	Pulpwood or scrap grapple*	Log grapple*	Chain-drag log conveyor*	Hand or power winch	Ice tongs, pike poles, spikes, etc.	Crane-mounted rope, fabric, or wire sling*	Vacuum hoses	Special pumps	Kelp harvesters*
X	X	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	X	0	0	0
0	0	X	XX	0	X	0	X	0	0	0
X	X	0	0	0	0	X	0	0	0	0
X	X	X	X	0	X	0	X	0	0	0
X	0	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	X	0	0	0
0	0	X	XX	0	X	0	X	0	0	0
X	X	X	X	0	0	X	0	0	0	0
X	X	XX	X	0	X	X	0	0	0	0
X	0	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	X	0	0	0
0	0	X	XX	0	X	0	X	0	0	0
X	X	0	0	0	0	0	0	X	X	0
X	X	XX	X	0	0	X	0	0	0	X
X	X	XX	X	0	0	X	0	0	0	X
X	X	XX	X	0	X	X	X	0	0	0

* - Recommended alternative to current practice, not reported previously used.

TABLE I.

SITUATION IV: Open ocean; debris uncontained and/or scattered; equipment can be permanently mounted on suitable vessel or temporarily mounted on vessel of opportunity suited to prevailing sea state.	Wire-mesh basket on articulated hydraulic crane or backhoe	Crane-mounted wire-mesh dragline-type basket	Front-end loading wire-mesh basket or rake	Clamshell-bucket-equipped crane	Debris conveyors	Oleophilic belt-type skimmers	Rakes, shovels, pitch-forks, dip nets, etc.	Chain-link or wire-mesh nets between catamaran hulls
DEBRIS CATEGORY:								
I. General Wood Items								
A. Small	XX	X	X	0	X	X	0	0
B. Medium	XX	X	X	0	X	0	0	0
C. Large	X	X	X	0	0	0	0	0
II. Non-Rigid Shapes								
A. Small	XX	X	X	0	X	X	0	0
B. Large	XX	X	X	0	X	0	0	0
III. Rigid Shapes								
A. Small	XX	X	X	0	X	X	0	0
B. Medium	XX	X	X	0	X	0	0	0
C. Large	X	X	X	0	0	0	0	0
IV. Flexible Sheets								
A. Small	XX	X	X	0	X	X	0	0
B. Large	X	X	X	0	0	0	0	0
V. Rigid Sheets								
A. Small	XX	X	X	0	X	X	0	0
B. Medium	XX	X	X	0	X	0	0	0
C. Large	X	X	X	0	0	0	0	0
VI. Amorphous Materials	X	X	X	0	X	X	0	0
VII. Filamentous Pieces								
A. Individual Pieces	X	X	X	0	0	0	0	0
B. Groups of Pieces	X	X	X	0	0	0	0	0
VIII. Special Cases	X	X	X	0	0	0	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Crane-mounted wire-mesh basket hung over side or bow of vessel	Trash or debris rakes mounted on hydraulic boom*	Pulpwood or scrap grapple*	Log grapple*	Chain-drag log conveyor*	Hand or power winch	Ice tongs, pike poles, spikes, etc.	Crane-mounted rope, fabric, or wire sling*	Vacuum hoses	Special pumps	Kelp harvesters*
XX	X	0	0	0	0	0	0	0	0	0
XX	X	X	X	0	0	0	X	0	0	0
0	0	X	XX	0	X	0	X	0	0	0
XX	X	0	0	0	0	0	0	0	0	0
X	X	X	X	0	X	0	X	0	0	0
XX	0	0	0	0	0	0	0	0	0	0
XX	XX	X	X	0	0	0	X	0	0	0
0	0	X	X	0	X	0	X	0	0	0
XX	X	X	X	0	0	0	0	0	0	0
X	X	X	X	0	X	0	0	0	0	0
XX	0	0	0	0	0	0	0	0	0	0
XX	X	X	X	0	0	0	X	0	0	0
0	0	X	X	0	X	0	X	0	0	0
XX	X	0	0	0	0	0	0	0	0	0
X	X	X	X	0	0	0	0	0	0	X
X	X	X	X	0	0	0	0	0	0	X
X	X	X	X	0	X	0	X	0	0	0

* - Recommended alternative to current practice, not reported previously used.

TABLE L.

SITUATION V: Very shallow water (1 - 2 ft) or intertidal zone; debris may or may not be contained by artificial or natural barrier; equipment can be mounted on amphibious vessels, such as DUKWs or LARCs or on shallow-draft barges, or on shore.	Wire-mesh basket on articulated hydraulic crane or backhoe	Crane-mounted wire-mesh dragline-type basket	Front-end loading wire-mesh basket on rake	Clamshell-bucket-equipped crane	Debris conveyors	Oleophilic belt-type skimmers	Rakes, shovels, pitch-forks, dip nets, etc.	Chain-link or wire-mesh nets between catamaran hulls
DEBRIS CATEGORY:								
I. General Wood Items								
A. Small	X	X	0	X	X	X	$\underline{X}$	0
B. Medium	X	X	0	X	X	0	$\underline{X}$	0
C. Large	X	X	0	X	0	0	0	0
II. Non-Rigid Shapes								
A. Small	X	X	0	X	X	X	$\underline{X}$	0
B. Large	X	X	0	X	X	0	0	0
III. Rigid Shapes								
A. Small	X	X	0	X	X	X	$\underline{X}$	0
B. Medium	X	X	0	X	X	0	$\underline{0}$	0
C. Large	X	X	0	X	0	0	0	0
IV. Flexible Sheets								
A. Small	X	X	0	X	X	X	$\underline{X}$	0
B. Large	X	X	0	X	0	0	$\underline{0}$	0
V. Rigid Sheets								
A. Small	X	X	0	X	X	X	$\underline{X}$	0
B. Medium	X	X	0	X	X	0	$\underline{0}$	0
C. Large	X	X	0	X	0	0	0	0
VI. Amorphous Materials	X	X	0	X	X	XX	$\underline{X}$	0
VII. Filamentous Pieces								
A. Individual Pieces	X	X	0	X	0	0	$\underline{X}$	0
B. Groups of Pieces	X	X	0	X	0	0	$\underline{X}$	0
VIII. Special Cases	X	X	0	X	0	0	$\underline{0}$	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

(Continued)

Crane-mounted wire-mesh basket hung over side or bow of vessel	Trash or debris rakes mounted on hydraulic boom*	Pulpwood or scrap grapple*	Log grapple*	Chain-drag log conveyor*	Hand or power winch	Ice tongs, pike poles, spikes, etc.	Crane-mounted rope, fabric, or wire sling *	Vacuum hoses	Special pumps	Kelp harvesters *
0	X	0	0	0	0	0	0	X	X	0
0	X	X	X	0	0	X	0	0	0	0
0	0	X	X	X	X	0	0	0	0	0
0	X	0	0	0	0	X	0	0	0	0
0	X	X	X	0	X	0	0	0	0	0
0	0	0	0	0	0	0	0	X	X	0
0	X	X	X	0	0	X	0	0	0	0
0	0	X	X	X	X	0	0	0	0	0
0	X	X	X	0	0	X	0	0	0	0
0	X	X	X	0	X	X	0	0	0	0
0	0	0	0	0	0	0	0	X	X	0
0	X	X	X	0	0	X	0	0	0	0
0	0	X	X	X	X	0	0	0	0	0
0	X	0	0	0	0	0	0	X	X	0
0	X	X	X	0	0	0	0	0	0	0
0	X	X	X	0	0	0	0	0	0	0
0	X	X	X	0	X	X	0	0	0	0

* - Recommended alternative to current practice, not reported previously used.

APPENDIX M

EVALUATION OF BEACH RECOVERY METHODS

Appendix M contains an evaluation of methods used in past spills for recovering debris from beaches.

For the key to symbols, refer to page 389.

TABLE M. BEACH RECOVERY

DEBRIS SITUATION I: Stable, sandy or gravel beach; accessible to heavy equipment.	Front-end loaders	Bulldozers	Backhoes	Trash or hay rakes	Modified road graders	Truck with winch	Pitchforks, rakes, shovels, hand pickup, etc.	Log-loading and stacking equipment	Log grapple	Pulpwood or scrap grapple	Clamshell bucket
DEBRIS CATEGORY:											
I. General Wood Items											
A. Small	$\underline{XX}$	$\underline{X}$	X	X	X	0	$\underline{X}$	0	0	XX	X
B. Medium	$\underline{XX}$	$\underline{X}$	$\underline{X}$	X	X	0	$\underline{X}$	0	0	XX	X
C. Large	$\underline{0}$	$\underline{X}$	0	0	0	$\underline{X}$	0	XX	XX	X	X
II. Non-Rigid Shapes											
A. Small	$\underline{XX}$	$\underline{X}$	X	X	0	0	$\underline{X}$	0	0	0	X
B. Large	$\underline{X}$	$\underline{X}$	X	X	X	0	0	X	X	XX	X
III. Rigid Shapes											
A. Small	$\underline{XX}$	$\underline{X}$	X	0	0	0	$\underline{X}$	0	0	0	X
B. Medium	$\underline{XX}$	$\underline{X}$	X	X	X	0	X	0	0	XX	X
C. Large	$\underline{0}$	$\underline{X}$	0	0	0	X	0	X	XX	X	X
IV. Flexible Sheets											
A. Small	$\underline{XX}$	$\underline{X}$	X	X	X	0	$\underline{X}$	0	0	X	X
B. Large	$\underline{X}$	$\underline{X}$	X	X	X	0	X	0	X	X	X
V. Rigid Sheets											
A. Small	$\underline{XX}$	$\underline{X}$	X	X	$\underline{0}$	0	X	0	0	0	X
B. Medium	$\underline{XX}$	$\underline{X}$	X	X	X	0	X	0	0	X	X
C. Large	$\underline{0}$	$\underline{X}$	0	0	0	X	0	0	0	0	0
VI. Amorphous Materials	$\underline{XX}$	$\underline{X}$	$\underline{X}$	$\underline{X}$	$\underline{X}$	0	$\underline{X}$	0	0	0	$\underline{X}$
VII. Filamentous Pieces											
A. Individual Pieces	$\underline{X}$	$\underline{X}$	$\underline{X}$	$\underline{X}$	$\underline{X}$	0	$\underline{X}$	0	0	X	$\underline{X}$
B. Groups of Pieces	$\underline{X}$	$\underline{X}$	$\underline{X}$	$\underline{X}$	$\underline{X}$	0	$\underline{X}$	0	0	X	$\underline{X}$
VIII. Special Cases	$\underline{X}$	$\underline{X}$	X	X	X	X	$\underline{X}$	0	X	X	X

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - Reported state-of-the-art

APPENDIX N

EVALUATION OF TEMPORARY STORAGE METHODS

Appendix N is an evaluation of containers and related techniques that have been used or could be used for temporary storage of debris.

For the key to symbols, refer to page 389.

TABLE N.

DEBRIS CATEGORY:	55-gallon drums	Bottoms and decks of work boats	Cardboard boxes	Wooden crates and baskets	Standard steel trash containers (e.g. Dumpsters)	Perforated steel trash containers*	Scow barges	Flat barges	Debris nets	Recovered oil-storage tanks	Plastic trash bags
I. General Wood Items											
A. Small	<u>X</u>	<u>0</u>	0	<u>X</u>	<u>XX</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	<u>0</u>	<u>0</u>
B. Medium	0	<u>X</u>	0	<u>X</u>	<u>XX</u>	XX	<u>X</u>	<u>X</u>	<u>XX</u>	0	0
C. Large	0	X	0	0	<u>X</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	0	0
II. Non-Rigid Shapes											
A. Small	<u>X</u>	<u>0</u>	0	X	<u>XX</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	<u>0</u>	<u>X</u>
B. Large	0	X	0	X	<u>XX</u>	XX	<u>X</u>	<u>X</u>	<u>XX</u>	0	0
III. Rigid Shapes											
A. Small	<u>X</u>	<u>0</u>	0	X	<u>XX</u>	0	<u>X</u>	<u>X</u>	<u>0</u>	<u>0</u>	X
B. Medium	0	<u>X</u>	0	X	<u>XX</u>	XX	<u>X</u>	<u>X</u>	<u>XX</u>	0	0
C. Large	0	X	0	0	<u>X</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	0	0
IV. Flexible Sheets											
A. Small	<u>X</u>	<u>0</u>	0	<u>X</u>	<u>XX</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	0	X
B. Large	<u>X</u>	<u>X</u>	0	<u>X</u>	<u>XX</u>	XX	<u>X</u>	<u>X</u>	<u>XX</u>	0	0
V. Rigid Sheets											
A. Small	<u>X</u>	<u>0</u>	0	X	<u>XX</u>	0	<u>X</u>	<u>X</u>	<u>0</u>	<u>0</u>	X
B. Medium	0	<u>X</u>	0	X	<u>XX</u>	XX	<u>X</u>	<u>X</u>	<u>XX</u>	0	0
C. Large	0	X	0	0	<u>X</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	0	0
VI. Amorphous Materials	<u>X</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>XX</u>	0	<u>X</u>	<u>0</u>	0	<u>0</u>	<u>X</u>
VII. Filamentous Pieces											
A. Invididual Pieces	<u>X</u>	<u>0</u>	<u>0</u>	<u>X</u>	<u>XX</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	<u>0</u>	<u>X</u>
B. Groups of Pieces	<u>X</u>	<u>0</u>	<u>0</u>	<u>X</u>	<u>XX</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	<u>0</u>	<u>X</u>
VIII. Special Cases	0	<u>X</u>	0	0	<u>XX</u>	X	<u>X</u>	<u>X</u>	<u>X</u>	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - Reported state-of-the-art

TEMPORARY STORAGE

Debris Category	Metal or plastic trash cans	Floating debris containers *	Dump trucks or trash trucks on barges or nearby shore *
I.			
A.	X	X	XX
B.	0	X	XX
C.	0	0	X
II.			
A.	X	X	XX
B.	0	X	XX
III.			
A.	X	X	XX
B.	0	X	XX
C.	0	0	XX
IV.			
A.	X	X	XX
B.	X	X	XX
V.			
A.	X	X	XX
B.	0	X	XX
C.	0	0	XX
VI.	X	X	XX
VII.			
A.	X	X	XX
B.	X	X	XX
VIII.	0	0	X

* - Recommended alternative to current practice, not reported previously used.

APPENDIX O

EVALUATION OF DEBRIS PROCESSING METHODS

Appendix O contains an evaluation of methods that have been or could be used for processing of debris on scene to reduce debris-handling problems in oil-spill recovery operations.

For the key to symbols, refer to page 389.

TABLE 0.

DEBRIS CATEGORY:	Reclaim useable items of debris for salvage, recycling, or return to orginal owner	a) by hand	b) by grapple-equipped crane	Sort by category, size, etc.	a) by hand	b) by mechanized sorters such as vibrating screens *	Wash debris to remove oil using dewatering screens, steam or hot water jets, etc.*
I. General Wood Items							
A. Small		X	0		0	X	X
B. Medium		X	X		X	X	X
C. Large		0	X		0	0	X
II. Non-Rigid Shapes							
A. Small		X	0		X	X	X
B. Large		X	X		0	X	X
III. Rigid Shapes							
A. Small		X	0		0	X	X
B. Medium		X	X		X	X	X
C. Large		0	X		0	0	X
IV. Flexible Sheets							
A. Small		X	0		X	0	0
B. Large		0	X		X	0	0
V. Rigid Sheets							
A. Small		X	0		0	X	X
B. Medium		X	X		X	X	X
C. Large		0	X		X	0	X
VI. Amorphous Material		0	0		0	0	0
VII. Filamentous Pieces							
A. Individual Pieces		X	X		0	0	0
B. Groups of Pieces		X	X		0	0	0
VIII. Special Cases		X	X		X	X	X

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art

Debris Category	Reduce debris size with grinders, mulchers, shredders, etc.	a) small*	b) medium*	c) large*	Reduce debris volume with compaction	a) small*	b) medium*	c) large*	Mix with straw or other sorbents	a) in storage containers	b) on vibrating screens, conveyors, etc.*	Hand or power saw
I.												
A.		X	X	X		0	0	0		X	X	0
B.		X	X	X		0	0	0		X	X	0
C.		0	0	X		0	0	0		0	0	X
II.												
A.		X	X	X		X	X	X		X	X	0
B.		0	X	X		0	X	X		0	0	0
III.												
A.		X	X	X		X	X	X		X	X	0
B.		0	X	X		0	X	X		X	X	0
C.		0	0	X		0	0	X		0	0	X
IV.												
A.		X	X	X		X	X	X		X	X	0
B.		0	X	X		0	X	X		0	0	C
V.												
A.		X	X	X		X	X	X		X	X	0
B.		0	X	X		0	X	X		X	X	0
C.		0	0	X		0	0	X		0	0	X
VI.		0	0	0		0	0	0		X	X	0
VII.												
A.		0	X	X		0	X	X		X	X	0
B.		0	X	X		0	X	X		X	X	0
VIII.		0	X	X		0	X	X		0	0	0

* - Recommended alternative to current practice, not reported previously used.

APPENDIX P

EVALUATION OF METHODS FOR TRANSFER OF DEBRIS

Appendix P contains evaluations of methods for the transfer of debris on the recovery site.

For the key to symbols, refer to page 389.

Preceding page blank

TABLE P.

DEBRIS CATEGORY:	Manual transfer of individual items of debris	Manual transfer of debris containers such as 55-gallon drums, bushel baskets, plastic bags, etc.	Grapple or clamshell equipment crane to offload non-containerized debris	Crane to offload "non-standard" containers such as 55-gallon drums	Crane to offload standard trash containers	Crane to hoist floating debris containers*	Crane to offload filled debris nets
I. General Wood Items							
A. Small	0	X	0	X	XX	X	0
B. Medium	X	0	X	0	XX	X	X
C. Large	0	0	X	0	X	0	X
II. Non-Rigid Shapes							
A. Small	X	X	0	X	XX	X	0
B. Large	0	0	X	0	XX	X	X
III. Rigid Shapes							
A. Small	0	X	0	X	XX	X	0
B. Medium	X	0	X	0	XX	X	X
C. Large	0	0	X	0	X	0	X
IV. Flexible Sheets							
A. Small	X	X	0	X	XX	X	X
B. Large	X	X	X	X	XX	X	X
V. Rigid Sheets							
A. Small	0	X	0	X	XX	X	0
B. Medium	X	0	X	0	XX	X	X
C. Large	0	0	0	0	XX	0	X
VI. Amorphous Material	0	X	0	X	XX	X	0
VII. Filamentous Pieces							
A. Individual Pieces	X	X	X	X	XX	X	X
B. Groups of Pieces	X	X	X	X	XX	X	X
VIII. Special Cases	X	X	X	X	XX	X	X

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art;

Debris Category	Conveyor system for off-loading non-containerized debris*	Conveyor system for off-loading debris containers*	Direct offloading of filled trash or dump trucks*	Vacuum Hoses
I.				
A.	X	X	XX	0
B.	X	0	XX	0
C.	0	0	X	0
II.				
A.	X	X	XX	0
B.	0	0	XX	0
III.				
A.	X	X	XX	X
B.	X	0	XX	0
C.	0	0	X	0
IV.				
A.	X	X	XX	0
B.	0	X	XX	0
V.				
A.	X	X	XX	X
B.	X	0	X	0
C.	0	0	XX	0
VI.	X	X	XX	XX
VII.				
A.	0	X	XX	0
B.	0	X	XX	0
VIII.	0	X	XX	0

* - Recommended alternative to current practice, not reported previously used.

APPENDIX Q

EVALUATION OF METHODS FOR TRANSPORTING DEBRIS

Appendix Q contains an evaluation of methods of transport for various types of debris.

For the key to symbols, refer to page 389.

TABLE 9. TRANSPORT

DEBRIS CATEGORY:	Dump trucks	Trash trucks	Stake trucks or flatbed tractor-trailers	Railroad hopper cars	Scow or flat barges	Logging trucks*	Vacuum trucks
I. General Wood Items							
A. Small	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{0}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	0	0
B. Medium	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
C. Large	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	$\underline{\text{X}}$	X	0
II. Non-Rigid Shapes							
A. Small	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{0}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
B. Large	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	0	$\underline{\text{X}}$	0	0
III. Rigid Shapes							
A. Small	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{0}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	0	X
B. Medium	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
C. Large	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	$\underline{\text{X}}$	0	0
IV. Flexible Sheets							
A. Small	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{0}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
B. Large	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{0}}$	$\underline{\text{0}}$	$\underline{\text{X}}$	0	0
V. Rigid Sheets							
A. Small	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{0}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	X
B. Medium	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
C. Large	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	$\underline{\text{X}}$	0	0
VI. Amorphous Material	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{0}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	XX
VII. Filamentous Pieces							
A. Individual Pieces	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
B. Groups of Pieces	$\underline{\text{XX}}$	$\underline{\text{XX}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{X}}$	0	0
VIII. Special Cases	$\underline{\text{X}}$	$\underline{\text{X}}$	$\underline{\text{0}}$	0	$\underline{\text{X}}$	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art;

APPENDIX R

EVALUATION OF DEBRIS DISPOSAL METHODS

Appendix R contains an evaluation of methods for the disposal of various categories of debris.

For the key to symbols, refer to page 389.

TABLE R. DISPOSAL METHOD

DEBRIS CATEGORY:	Landfill dumping	Open burning	Controlled burning (no visible smoke)*	Incineration (meets air pollution standards)*	Salvaged, recycled, returned to original owners, etc.	Processed for boiler fuel*	Sold or donated for fire-wood*	Processed for soil conditioner (compost)
I. General Wood Items								
A. Small	X	0	XX	XX	X	XX	0	X
B. Medium	X	0	XX	XX	X	XX	X	X
C. Large	X	0	XX	XX	XX	X	XX	X
II. Non-Rigid Shapes								
A. Small	X	0	XX	XX	X	XX	0	X
B. Large	X	0	XX	XX	X	XX	0	X
III. Rigid Shapes								
A. Small	X	0	XX	XX	X	XX	0	X
B. Medium	X	0	XX	XX	X	XX	X	X
C. Large	X	0	XX	XX	X	XX	X	X
IV. Flexible Sheets								
A. Small	X	0	XX	XX	X	XX	0	X
B. Large	X	0	XX	XX	X	XX	0	X
V. Rigid Sheets								
A. Small	X	0	XX	XX	X	XX	0	X
B. Medium	X	0	XX	XX	X	XX	X	X
C. Large	X	0	XX	XX	X	XX	X	X
VI. Amorphous Material	X	0	0	0	X	XX	0	X
VII. Filamentous Pieces								
A. Individual Pieces	X	0	XX	XX	X	XX	0	X
B. Groups of Pieces	X	0	XX	XX	X	XX	0	X
VIII. Special Cases	X	0	0	0	XX	X	0	0

XX - Preferred; X - Acceptable; 0 - Unacceptable
Underline - reported state-of-the-art;

APPENDIX S

OBSERVED OR PROBABLE EFFECTS OF DEBRIS ON POLLUTION-RESPONSE EQUIPMENT

Appendix S contains a summary of observed or probable effects of various categories of debris on pollution-response equipment.

TABLE S. OBSERVED OR PROBABLE EFFECTS OF DEBRIS ON POLLUTION-RESPONSE EQUIPMENT

Containment Devices

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Small	Breaking when in large quantities
		Puncturing, tearing, and chafing (especially metal in wood pieces)
		Upsetting trim (when in large quantities)
		Snagging
	Medium	Breaking
		Puncturing, tearing, and chafing (especially metal in wood pieces)
		Sinking
		Forced submergence
		Lifting up of boom
		Upsetting trim
		Snagging
		Deployment hindrance
	Large	Breaking
		Puncturing, tearing, and chafing (especially metal in wood pieces)
		Sinking
		Forced submergence
		Lifting up
		Upsetting trim
		Snagging
		Deployment hindrance

TABLE S. (Continued)
Containment Devices

Debris Category	Debris Subcategory	Effect on Equipment
Category II: Non-Rigid Shapes (dead fish, dead birds, etc.)	Small	Breaking when in large quantities Upsetting when in large quantities Snagging
	Large	Breaking Upsetting trim Snagging Deployment hindrance
Category III: Rigid Shapes (boats, crates, etc.)	Small	Breaking when in large quantities Upsetting trim when in large quantities
	Medium	Breaking Puncturing, tearing, and chafing Sinking Forced submergence Lifting up Upsetting trim Snagging Deployment hindrance
	Large	Breaking Puncturing, tearing, and chafing Sinking Forced submergence Lifting up Upsetting trim

TABLE S. (Continued)

Containment Devices

Debris Category	Debris Subcategory	Effect on Equipment
		Snagging Deployment hindrance
Category IV: Flexible Sheets (canvas, rags, plastic, etc.)	Small	Breaking when in large quantities Upsetting trim when in large quantities Snagging
	Large	Breaking when in large quantities Upsetting trim Snagging Deployment hindrance
Category V: Rigid Sheets (plastic, plywood, etc.)	Small	Breaking when in large quantities Puncturing and tearing when in large quantities Upsetting trim when in large quantities
	Medium	Breaking Puncturing and tearing Sinking Lifting up Upsetting trim Snagging Deployment hindrance
	Large	Breaking Puncturing, tearing, and chafing

TABLE S. (Continued)

Containment Devices

Debris Category	Debris Subcategory	Effect on Equipment
		Sinking
		Forced submergence
		Lifting up
		Upsetting trim
		Snagging
		Deployment hindrance
Category VI: Amorphous Material (wax, grease, etc.)		Breaking when in large quantities
		Upsetting trim when in large quantities
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces	Snagging
		Deployment hindrance
	Groups of Pieces	Breaking when in large quantities
		Upsetting trim
		Snagging
		Deployment hindrance
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaced Objects	Breaking
		Puncturing and tearing
		Sinking
		Forced submergence
		Upsetting trim

TABLE S. (Continued)

Containment Devices

Debris Category	Debris Subcategory	Effect on Equipment
		Snagging
		Deployment hindrance
(milk cartons, soap cartons, etc.)	Fabricated Paper Items	Breaking when in large quantities
		Upsetting trim when in large quantities
		Snagging

TABLE S. (Continued)

Recovery Equipment - Transfer Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Small	Prevention of diaphragm-pump check-valve seating Clogging of piping systems Jamming and seizing of rotating pumps Pump wearing and pump breakage
	Medium and Large	Blocking of intake opening
Category II: Non-Rigid Shapes (dead fish, dead birds, etc.)	Small and Large	Blocking of intake opening
Category III: Rigid Shapes (boats, crates, etc.)	Small	Prevention of diaphragm-pump check-valve seating Clogging of piping systems Breaking of pump components Jamming and seizing of rotating pumps
	Medium and Large	Blocking of intake opening
Category IV: Flexible Sheets (canvas, rags, sheet plastic, etc.)	Small and Large	Blocking of intake opening Jamming and seizing of rotating pumps Prevention of diaphragm-pump check-valve seating

TABLE S. (Continued)
Recovery Equipment - Transfer Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category V: Rigid Sheets (plastic, plywood, etc.)	Small	Clogging of piping systems Jamming and seizing of rotating pumps
	Medium and Large	Blocking of intake opening
Category VI: Amorphous Material (wax, grease, etc.)		Blocking of intake opening
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces	Jamming and seizing of rotating pumps Prevention of diaphragm-pump check-valve seating
	Groups of Pieces	Blocking of intake opening
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaces Objects	Blocking of intake opening
(milk cartons, soap cartons, etc.)	Fabricated Paper Items	Blocking of intake opening

TABLE S. (Continued)

Recovery Equipment - Weir Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category I General Wood Items (boards, logs, tree limbs, etc.)	Small	Bridging Reservoir clogging
	Medium and Large	Bridging Upsetting of trim Displacement changes Physical damage Reservoir clogging Sinking and forced submergence
Category II Non-Rigid Shapes (dead fish, dead birds, etc.)	Small	Bridging Reservoir clogging
	Large	Bridging Upsetting of trim Displacement change Sinking and forced submergence
Category III: Rigid Shapes (boats, crates, etc.)	Small	Bridging Reservoir clogging
	Medium	Bridging Upsetting trim Displacement change Physical damage Reservoir clogging Sinking and forced submergence

TABLE S. (Continued)

Recovery Equipment - Weir Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
	Large	Upsetting trim Physical damage Sinking and forced submergence
Category IV: Flexible Sheets (canvas, rags, plastic, etc.)	Small and Large	Bridging Upsetting trim Reservoir clogging
Category V: Rigid Sheets (plastic, plywood, etc.)	Small	Bridging Reservoir clogging
	Medium and Large	Bridging Upsetting trim Physical damage Reservoir clogging Sinking and forced submergence
Category VI: Amorphous Materials (wax, grease, etc.)		Bridging Reservoir clogging
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces and Groups of Pieces	Bridging Upsetting trim Displacement change Reservoir clogging

TABLE S. (Continued)

Recovery Equipment - Weir Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaced Objects	Bridging
		Physical damage
		Reservoir clogging
	Fabricated Paper Items (milk cartons, soap cartons, etc.)	Bridging
		Reservoir clogging

TABLE S. (Continued)

Recovery Equipment - Rotating Drum, Disc, Belt Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Small	Bridging Mechanical jamming Disc wiper damage Sorbent belt clogging Debris wiping off recovered fluid
	Medium and Large	Bridging Mechanical jamming Physical damage due to impact Tearing of sorbent materials Debris wiping off recovered fluid
Category II: Non-Rigid Shapes (dead fish, dead birds, etc.)	Small and Large	Bridging Debris wiping off recovered fluid
Category III: Rigid Shapes (boats, crates, etc.)	Small	Bridging Mechanical jamming Sorbent belt clogging Debris wiping off recovered fluid
	Medium and Large	Bridging Mechanical jamming Physical damage due to impact Tearing of sorbent materials
Category IV: Flexible Sheets (canvas, rags, plastic, etc.)	Small and Large	Bridging Mechanical jamming

TABLE S. (Continued)

Recovery Equipment - Rotating Drum, Disc, Belt Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category V: Rigid Sheets (plastic, plywood, etc.)	Small	Bridging
		Mechanical jamming
		Sorbent belt clogging
		Debris wiping off recovered fluid
	Medium and Large	Bridging
		Mechanical jamming
		Impact and catastrophic failure
		Tearing sorbent materials
		Debris wiping off recovered fluid
Category VI: Amorphous Material (wax, grease, etc.)		Bridging
Category VII: Filamentous (seaweed, hay, grass, etc.)	Individual Pieces and Groups of Pieces	Bridging
		Mechanical jamming
		Sorbent belt clogging
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaced Objects	Bridging
		Impact and catastrophic failure
		Debris wiping off recovered fluid
(milk cartons, soap cartons, etc.)	Fabricated Paper Items	Bridging
		Debris wiping off recovered spill

TABLE S. (Continued)
Recovery Equipment - Dynamic-Inclined-Plane Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Medium	Bridging Clogging of reservoir
	Large	Bridging
Category II: Non-Rigid Shapes (dead fish, dead birds, etc.)	Large	Bridging Clogging of reservoir
Category III: Rigid Shapes (boats, crates, etc.)	Medium	Bridging Clogging of reservoir
	Large	Bridging
Category IV: Flexible Sheets (canvas, rags, plastic, etc.)	Large	Bridging Clogging of reservoir
Category V: Rigid Sheets (plastic, plywood, etc.)	Medium	Bridging Clogging of reservoir
	Large	Bridging
Category VI: Amorphous Materials (wax, grease, etc.)		Not observed
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces and Groups of Pieces	Bridging Clogging of reservoir

TABLE S. (Continued)
Recovery Equipment - Dynamic-Inclined-Plane Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaces Objects	Bridging
(milk cartons, soap cartons, etc.)	Fabricated Paper Items	Bridging Clogging of reservoir

TABLE S. (Continued)

Recovery Equipment - Sorbent Material Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Small, Medium and Large	Dispersement Impairs recovery
Category II: Non-Rigid Shapes (dead fish, dead birds, etc.)	Small and Large	Dispersement Impairs recovery
Category III: Rigid Shapes (boats, crates, etc.)	Small, Medium and Large	Dispersement Impairs recovery
Category IV: Flexible Sheets (canvas, rags, plastic, etc.)	Small and Large	Impairs recovery
Category V: Rigid Sheets (plastic, plywood, etc.)	Small, Medium and Large	Dispersement
Category VI: Amorphous Material (wax, grease, etc.)		Not observed
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces and Groups of Pieces	Dispersement Impairs recovery

TABLE S. (Continued

Recovery Equipment - Sorbent Material Skimming Systems

Debris Category	Debris Subcategory	Effect on Equipment
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaced Objects	Dispersement
(milk cartons, soap cartons, etc.)	Fabricated Paper Items	Dispersement Impairs recovery

TABLE S. (Continued)

Auxiliary Equipment - Boats

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Small	Fouling of water intakes
	Medium and Large	Hull damage
		Impairs navigation and maneuverability
		Breaking of propellers
		Fouling of water intakes
		Impairment of stability
		Impairment of personel safety
Category II. Non-Rigid Shapes (dead fish, dead birds, etc.)	Small	Fouling of water intakes
	Large	Impairs navigation and maneuverability
		Fouling of propellers
		Fouling of water intakes
		Impairment of stability
		Impairment of personnel safety
Category III: Rigid Shapes (boats, crates, etc.)	Small	Fouling of water intakes
	Medium and Large	Hull damage
		Impairs navigation and maneuverability
		Breaking of propellers
		Fouling of water intakes
		Impairment of stability
		Impairment of personnel safety

TABLE S. (Continued)
Auxiliary Equipment - Boats

Debris Category	Debris Subcategory	Effect on Equipment
Category IV: Flexible Sheets (canvas, rags, plastic, etc.)	Small and Large	Impairs navigation and maneuverability
		Fouling of propellers
		Fouling of water intakes
Category V: Rigid Sheets (plastic, plywood, etc.)	Small	Fouling of water intakes
	Medium and Large	Hull damage
		Impairs navigation and maneuverability
		Breaking of propellers
		Impairment of stability
		Impairment of personnel safety
Category VI: Amorphous Material (wax, grease, etc.)		Fouling of water intakes
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces and Groups of Pieces	Impairs navigation and maneuverability
		Fouling of propellers
		Fouling of water intakes

TABLE S. (Continued)

Auxiliary Equipment - Boats

Debris Category	Debris Subcategory	Effect on Equipment
Category VIII: Special Cases (coconuts, bottles, etc.)	Circular or Spherical Surfaced Objects	Hull damage
		Impairs navigation and maneuverability
		Breaking of propellers
		Fouling of water intakes
		Impairment of stability
		Impairment to personnel safety
(milk cartons, soap cartons, etc.)	Fabricated Paper items	Fouling of water intakes

TABLE S. (Continued)

Auxiliary Equipment - Temporary Storage Containers

Debris Category	Debris Subcategory	Effect on Equipment
Category I: General Wood Items (boards, logs, tree limbs, etc.)	Small	Reduction of capacity Clogging
	Medium and Large	Puncturing and tearing
Category II: Non-Rigid Shapes (dead fish, dead birds, etc.)	Small	Reduction of capacity Clogging
Category III: Rigid Shapes (boats, crates, etc.)	Small	Reduction of capacity Clogging
	Medium and Large	Puncturing and tearing
Category IV: Flexible Sheets (canvas, rags, etc.)	Small	Clogging
Category V: Rigid Sheets (plastic, plywood, etc.)	Small	Reduction of capacity Clogging
	Medium and Large	Puncturing and tearing
Category VI: Amorphous Material (wax, grease, etc.)		Clogging
Category VII: Filamentous Pieces (seaweed, hay, grass, etc.)	Individual Pieces and Groups of Pieces	Reduction of capacity Clogging

TABLE S. (Continued)

Auxiliary Equipment - Temporary Storage Containers

Debris Category	Debris Subcategory	Effect on Equipment
Category VIII: Special cases (coconuts, bottles, etc.)	Circular or Spherical Surfaced Objects	Reduction of capacity
		Clogging
		Puncturing and tearing
(milk cartons, soap cartons, etc.)	Fabricated Paper Items	Clogging

APPENDIX T

CURRENT EQUIPMENT DEBRIS EFFECT DESIGN FEATURES AND PROTECTION TECHNIQUES

Appendix T contains a listing of design features and protection techniques currently used to avoid or minimize debris effects on pollution-response equipment.

TABLE T. CURRENT EQUIPMENT DEBRIS-EFFECT DESIGN FEATURES AND PROTECTION TECHNIQUES

Containment Devices

Effect	Design Feature/Protection Technique
Breaking	Design Feature - High-strength materials or strength members, tensile elasticity to reduce debris impact forces, quick repair connections. Protection Technique - Debris handling; manual tending; diversionary deployment
Puncturing, Tearing and Chafing	Design Feature - Materials with high relative toughness; replaceable sections. Protection Technique - Manual tending; patching; use of double barriers; attached protective barrier.
Upsetting of Trim (in fence-type barriers)	Design Feature - Large relative righting moment. Protection Technique - Debris handling; use of double barriers.
Forced Submergence	Design Feature - Reserve buoyancy. Protection Technique - Manual tending; debris handling.
Sinking	Design Feature - Compartmentalized flotation; redundant flotation systems. Protection Technique - See puncturing, tearing, and chafing.

TABLE T. (Continued)

Containment Devices (Continued)

Effect	Design Feature/Protection Technique
Snagging	Design Feature - Smooth external surfaces. Protection Technique - Manual tending; debris handling.
Lifting Up	Design Feature - Greater draft; stiffer section. Protection Technique - Manual tending; debris handling.
Deployment Hindrance	Design Feature - Smooth exterior surfaces. Protection Technique - Debris handling.

TABLE T. (Continued)

Recovery Equipment

Effect	Design Feature/Protection Technique
	Fluid Transfer Systems
Prevention of Check Valve Seating	Design Feature - Intake trash screens; filters; easy cleaning or replacement of components. Protection Technique - Manual tending; debris handling.
Clogging of System Piping	Design Feature - Large diameter piping with large radius bends; easily replaced or cleaned components; backflushing; trash screens and filters. Protection Technique - Manual tending.
Jamming and/or Siezing of Rotating Pumps	Design Feature - Intake trash screens; in-line filters; use of pumps designed for handling solids. Protection Technique - Manual tending; debris reremoval/handling; easily disassembled pumps.
Wearing and Breakage of Pumps	Design Feature - Severe service pumps. Protection Technique - None used.
Blocking of Intake Opening	Design Feature - Intake trash screens; back flushing. Protection Technique - Manual tending.

TABLE T. (Continued)

Recovery Equipment (Continued)

Effect	Design Feature/Protection Technique
	Skimming Systems Weirs
Bridging	Design Feature - Trash screens. Protection Technique - Protective debris boom; debris handling.
Reservoir Clogging	Design Feature - Intake trash screens; protective boom barriers. Protection Technique - Debris handling; manual removal of debris.
Upsetting of Trim	Design Feature - Trash screens. Protection Technique - Debris handling; manual tending.
Physical Damage Due to Impact of Debris	Design Feature - Trash screens; strong support structures. Protection Technique - Protective barriers; debris handling.
Displacement Changes	Design Feature - None Protection Technique - Debris handling; manual tending.
Sinking and Forced Submergence	See Physical Damage Due to Impact of Debris.

TABLE T. (Continued)

Recovery Equipment (Continued)

Effect	Design Feature/Protection Technique
Skimming Systems	
Rotating Drum, Disc, and Belt	
Bridging	Design Feature - Trash screens. Protection Technique - Debris handling; manual tending; protective barriers.
Mechanical Jamming	Design Feature - Trash screens; shielding of components; isolation of machinery. Protection Technique - Debris handling; protective barriers.
Disc Wiper Damage	Design Feature - Trash screen. Protection Technique - Same as Mechanical Jamming.
Sorbent Belt Clogging	Design Feature - None. Protection Technique - None.
Debris Wiping Oil Off of Sorbent	Design Feature - Trash screens. Protection Technique - Same as Bridging.
Teaming of Sorbent Material	Same as above.
Physical Damage Due to Impace	Design Feature - Same as above. Protection Technique - Same as Bridging.

TABLE T. (Continued)

Recovery Equipment (Continued)

Effect	Design Feature/Protection Technique
	Skimming Systems **Dynamic Inclined Plane**
Bridging	Same as Bridging of Rotating Disc, Drum and Belt Skimmers.
Clogging of Reservoir	Design Feature - Metal debris screen. Protection Technique - Debris handling; manual tending; protective barrier.

TABLE T. (Continued)

Recovery Equipment (Continued)

Effect	Desgin Feature/Protection Technique
	<u>Skimming Systems</u>
	<u>Sorbent Material</u>
Dispersement	Design Feature - None.
	Protection Technique - Debris handling; protective barriers.
Impairs Recovery	Design Feature - None.
	Protection Techniques - Same as above.

TABLE T. (Continued)

Recovery Equipment (Continued)

Effect	Design Feature/Protection Technique
	Auxillary Equipment
	Boats
Hull Damage	Design Feature - With most craft, none. Protection Technique - Careful navigation. Use of poles and land skimmers.
Impairment of Navigation and Maneuverability	Design Feature - Side thruster and/or jet drives. Protection Technique - None.
Breaking of Propellers	Design Feature - Heavy duty propellers; propeller shrouds. Protection Technique - None.
Fouling of Water Intakes	Design Feature - Engine inlet location. Protection Technique - None.
Stability	Design Feature - None. Protection Technique - Caution in handling.
Impairment of Personel Safety	Design Feature - None Protection Technique - None.
Fouling of Propellers	Design Feature - Propeller cages or jet drive units. Protection Technique - None.

TABLE T. (Continued)

Recovery Equipment (Continued)

Effect	Design Feature/Protection Technique
	Auxiliary Equipment
	Temporary Storage Vessels
Reduction of Capacity	Design Feature - None. Protection Technique - Avoidance of ingestion of debris.
Clogging	See Recovery Equipment - Fluid Transfer Systems.
Puncturing and Tearing	See Containment Devices.

GPO 878-479